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Occupational Hygiene: Control of Exposures Through Intervention

After a hazard has been recognized and evaluated, the most appropriate interventions (methods of control) for a particular hazard must be determined. Control methods usually fall into three categories:

1. engineering controls
2. administrative controls
3. personal protective equipment.

As with any change in work processes, training must be provided to ensure the success of the changes.

Engineering controls are changes to the process or equipment that reduce or eliminate exposures to an agent. For example, substituting a less toxic chemical in a process or installing exhaust ventilation to remove vapours generated during a process step, are examples of engineering controls. In the case of noise control, installing sound-absorbing materials, building enclosures and installing mufflers on air exhaust outlets are examples of engineering controls. Another type of engineering control might be changing the process itself. An example of this type of control would be removal of one or more degreasing steps in a process that originally required three degreasing steps. By removing the need for the task that produced the exposure, the overall exposure for the worker has been controlled. The advantage of engineering controls is the relatively small involvement of the worker, who can go about the job in a more controlled environment when, for instance, contaminants are automatically removed from the air. Contrast this to the situation where the selected method of control is a respirator to be worn by the worker while performing the task in an “uncontrolled” workplace. In addition to the employer actively installing engineering controls on existing equipment, new equipment can be purchased that contains the controls or other more effective controls. A combination approach has often been effective (i.e., installing some engineering controls now and requiring personal protective equipment until new equipment arrives with more effective controls that will eliminate the need for personal protective equipment). Some common examples of engineering controls are:

- ventilation (both general and local exhaust ventilation)
- isolation (place a barrier between the worker and the agent)
- substitution (substitute less toxic, less flammable material, etc.)
- change the process (eliminate hazardous steps).

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The occupational hygienist must be sensitive to the worker’s job tasks and must solicit worker participation when designing or selecting engineering controls. Placing barriers in the workplace, for example, could significantly impair a worker’s ability to perform the job and may encourage “work arounds”. Engineering controls are the most effective methods of reducing exposures. They are also, often, the most expensive. Since engineering controls are effective and expensive it is important to maximize the involvement of the workers in the selection and design of the controls. This should result in a greater likelihood that the controls will reduce exposures.

Administrative controls involve changes in how a worker accomplishes the necessary job tasks—for example, how long they work in an area where exposures occur, or changes in work practices such as improvements in body positioning to reduce exposures. Administrative controls can add to the effectiveness of an intervention but have several drawbacks:

1. Rotation of workers may reduce overall average exposure for the workday but it provides periods of high short-term exposure for a larger number of workers. As more becomes known about toxicants and their modes of action, short-term peak exposures may represent a greater risk than would be calculated based on their contribution to average exposure.
2. Changing work practices of workers can present a significant enforcement and monitoring challenge. How work practices are enforced and monitored determines whether or not they will be effective. This constant management attention is a significant cost of administrative controls.

Personal protective equipment consists of devices provided to the worker and required to be worn while performing certain (or all) job tasks. Examples include respirators, chemical goggles, protective gloves and faceshields. Personal protective equipment is commonly used in cases where engineering controls have not been effective in controlling the exposure to acceptable levels or where engineering controls have not been found to be feasible (for cost or operational reasons). Personal protective equipment can provide significant protection to workers if worn and used correctly. In the case of respiratory protection, protection factors (ratio of concentration outside the respirator to that inside) can be 1,000 or more for positive-pressure supplied air respirators or ten for half-face air-purifying respirators. Gloves (if selected appropriately) can protect hands for hours from solvents. Goggles can provide effective protection from chemical splashes.

Intervention: Factors to Consider

Often a combination of controls is used to reduce the exposures to acceptable levels. Whatever methods are selected, the intervention must reduce the exposure and resulting hazard to an acceptable level. There are, however, many other factors that need to be considered when selecting an intervention. For example:

- effectiveness of the controls
- ease of use by the employee
- cost of the controls
- adequacy of the warning properties of the material
- acceptable level of exposure
- frequency of exposure
- route(s) of exposure
- regulatory requirements for specific controls.

Effectiveness of controls

Effectiveness of controls is obviously a prime consideration when taking action to reduce exposures. When comparing one type of intervention to another, the level of protection required must be appropriate for the challenge; too much control is a waste of resources. Those resources could be used to reduce other exposures or exposures of other employees. On the other hand, too little control leaves the worker exposed to unhealthy conditions. A useful first step is to rank the interventions according to their effectiveness, then use this ranking to evaluate the significance of the other factors.

Ease of use

For any control to be effective the worker must be able to perform his or her job tasks with the control in place. For example, if the control method selected is substitution, then the worker must know the hazards of the new chemical, be trained in safe handling procedures, understand proper disposal procedures, and so on. If the control is isolation—placing an enclosure around the substance or the worker—the enclosure must allow the worker to do his or her job. If the control measures interfere with the tasks of the job, the worker will be reluctant to use them and may find ways to accomplish the tasks that could result in increased, not decreased, exposures.

Cost

Every organization has limits on resources. The challenge is to maximize the use of those resources. When hazardous exposures are identified and an intervention strategy is being developed, cost must be a factor. The “best buy” many times will not be the lowest- or highest-cost solutions. Cost becomes a factor only after several viable methods of control have been identified. Cost of the controls can then be used to select the controls that will work best in that particular situation. If cost is the determining factor at the outset, poor or ineffective controls may be selected, or controls that interfere with the process in which the employee is working. It would be unwise to select an inexpensive set of controls that interfere with and slow down a manufacturing process. The process then would have a lower throughput and higher cost. In very short time the “real” costs of these “low cost” controls would become enormous. Industrial engineers understand the layout and overall process; production engineers understand the manufacturing steps and processes; the financial analysts understand the resource allocation problems. Occupational hygienists can provide a unique insight into these discussions due to their understanding of the specific employee’s job tasks, the employee’s interaction with the manufacturing equipment as well as how the controls will work in a particular setting. This team approach increases the likelihood of selecting the most appropriate (from a variety of perspectives) control.

Adequacy of warning properties

When protecting a worker against an occupational health hazard, the warning properties of the material, such as odour or irritation, must be considered. For example, if a semiconductor worker is working in an area where arsine gas is used, the extreme toxicity of the gas poses a significant potential hazard. The situation is compounded by arsine’s very poor warning properties—the workers cannot detect the arsine gas by sight or smell until it is well above acceptable levels. In this case, controls that are marginally effective at keeping exposures below acceptable levels should not be considered because excursions above acceptable levels cannot be detected by the workers. In this case, engineering controls should be installed to isolate the worker from the material. In addition, a continuous arsine gas monitor should be installed to warn workers of the failure of the engineering controls. In situations involving high toxicity and poor warning properties, preventive occupational hygiene is practised. The occupational hygienist must be flexible and thoughtful when approaching an exposure problem.

Acceptable level of exposure

If controls are being considered to protect a worker from a substance such as acetone, where the acceptable level of exposure may be in the range of 800 ppm, controlling to a level of 400 ppm or less may be achieved relatively easily. Contrast the example of acetone control to control of 2-ethoxyethanol, where the acceptable level of exposure may be in the range of 0.5 ppm. To obtain the same per cent reduction (0.5 ppm to 0.25 ppm) would probably require different controls. In fact, at these low levels of exposure, isolation of the material may become the primary means of control. At high levels of exposure, ventilation may provide the necessary reduction. Therefore, the acceptable level determined (by the government, company, etc.) for a substance can limit the selection of controls.

Frequency of exposure

When assessing toxicity the classic model uses the following relationship:

TIME x CONCENTRATION = DOSE

Dose, in this case, is the amount of material being made available for absorption. The previous discussion focused on minimizing (lowering) the concentration portion of this relationship. One might also reduce the time spent being exposed (the underlying reason for administrative controls). This would similarly reduce the dose. The issue here is not the employee spending time in a room, but how often an operation (task) is performed. The distinction is important. In the first example, the exposure is controlled by removing the workers when they are exposed to a selected amount of toxicant; the intervention effort is not directed at controlling the amount of toxicant (in many situations there may be a combination approach). In the second case, the frequency of the operation is being used to provide the appropriate controls, not to determine a work schedule. For example, if an operation such as degreasing is performed routinely by an employee, the controls may include ventilation, substitution of a less toxic solvent or even automation of the process. If the operation is performed rarely (e.g., once per quarter) personal protective equipment may be an option (depending on many of the factors described in this section). As these two examples illustrate, the frequency with which an operation is performed can directly affect the selection of controls. Whatever the exposure situation, the frequency with which a worker performs the tasks must be considered and factored into the control selection.

Route of exposure obviously is going to affect the method of control. If a respiratory irritant is present, ventilation, respirators, and so on, would be considered. The challenge for the occupational hygienist is identifying all routes of exposure. For example, glycol ethers are used as a carrier solvent in printing operations. Breathing-zone air concentrations can be measured and controls implemented. Glycol ethers, however, are rapidly absorbed through intact skin. The skin represents a significant route of exposure and must be considered. In fact, if the wrong gloves are chosen, the skin exposure may continue long after the air exposures have decreased (due to the employee continuing to use gloves that have experienced breakthrough). The hygienist must evaluate the substance—its physical properties, chemical and toxicological properties, and so on—to determine what routes of exposure are possible and plausible (based on the tasks performed by the employee).

In any discussion of controls, one of the factors that must be considered is the regulatory requirements for controls. There may well be codes of practice, regulations, and so on, that require a specific set of controls. The occupational hygienist has flexibility above and beyond the regulatory requirements, but the minimum mandated controls must be installed. Another aspect of the regulatory requirements is that the mandated controls may not work as well or may conflict with the best judgement of the occupational hygienist. The hygienist must be creative in these situations and find solutions that satisfy the regulatory as well as best practice goals of the organization.

Training and Labelling

Regardless of what form of intervention is eventually selected, training and other forms of notification must be provided to ensure that the workers understand the interventions, why they were selected, what reductions in exposure are expected, and the role of the workers in achieving those reductions. Without the participation and understanding of the workforce, the interventions will likely fail or at least operate at reduced efficiency. Training builds hazard awareness in the workforce. This new awareness can be invaluable to the occupational hygienist in identifying and reducing previously unrecognized exposures or new exposures.

Training, labelling and related activities may be part of a regulatory compliance scheme. It would be prudent to check the local regulations to ensure that whatever type of training or labelling is undertaken satisfies the regulatory as well as operational requirements.

Conclusion

In this short discussion on interventions, some general considerations have been presented to stimulate thought. In practice, these rules become very complex and often have significant ramifications for employee and company health. The occupational hygienist's professional judgement is essential in selecting the best controls. Best is a term with many different meanings. The occupational hygienist must become adept at working in teams and soliciting input from the workers, management and technical staff.