

TOXIC COMPOUNDS IN INDUSTRY

Contributions of the Industrial Hygienist

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The prevention of adverse health effects arising from occupational exposure to toxic compounds is certainly one of the major activities of the industrial hygienist, and may very well consume 90% of the time and effort expended for industrial hygiene activities in many organizations. It is imperative that the industrial hygienist be recognized as an essential member of a team of specialists concerned with occupational health and safety, and not operate in a world consisting only of air sampling pumps and OSHA standards.

The need for close working relationships with industrial physicians, nurses, safety specialists, and with increasing frequency, epidemiologists is great, and health and safety programs which operate as small autonomous units must be considered unsatisfactory. Having established this rather self-evident truth, let us briefly examine the industrial hygiene approach to dealing with toxic compounds as it has evolved to the present time.

Industrial hygiene is well defined as, "The recognition, evaluation and control of those environmental factors or stresses, arising in or from the work place, which may cause sickness, impaired health and well being, or significant discomfort and inefficiency among workers or among the citizens of the community" (1).

RECOGNITION

Although each of these activities is important, I believe the initial step of recognizing the potential for the existence of hazards due to toxic substances is of the greatest importance. It is frequently a routine matter to evaluate, by air sampling or other means, the magnitude of a hazard, and once measured, the control of the hazard may also be a routine engineering matter, but none of these activities will be initiated unless there is an awareness that a hazard may exist.

It is very important to establish whether or not the substances of interest can be expected to be present in the atmosphere as particulate suspensions, or as gases or vapors. Obviously the sampling technology will vary for each physical state, and on occasion it is difficult to make an exact prediction of the most probable physical state. Many compounds, particularly organic compounds of low or intermediate molecular weight, tend to have sufficient vapor pressure that although they may be disseminated as an aerosol, it is likely some of the substance will volatilize and be present as a vapor. If collection and analysis is limited to sampling by filtration, obviously the vapor portion will be lost.

For those substances which may exist in either the vapor or particulate phase, it will frequently be found that the permissible air concentration will be different for each physical state. Good examples of this phenomenon include the oil mist Threshold Limit Values (TLVs) and those for caprolactam. Experience has shown with the latter substance, for example, that the material is substantially more irritating when present as a fine dust suspension than when vaporized by the application of heat.

The personal monitoring devices normally give data which can be interpreted directly as time-weighted average exposure, thus making it a simple matter to determine the extent of compliance with standards which are expressed as time-weighted averages. It should be noted, however, that all time-weighted average exposure standards include provision for maximum excursions which may not be exceeded for more than specified periods of time. If it is suspected that higher concentrations may exist at any time during the work cycle, it then becomes necessary to sample by some other means to determine, for example, the 15-minute concentration which might be experienced.

In other cases standards are designated as "ceiling" values, or as short term levels of some kind that must not be exceeded. Clearly the long term measurements obtainable by the personal monitors are not always adequate for such measurements.

It is worthwhile to note that although personal monitoring is required by many federal standards, it is still useful on many occasions to perform what is generally designated as an area sampling, with a device maintained in a fixed location. A large lead and zinc smelter, for example, continues to monitor nearly 100 fixed points

routinely, in addition to providing required personal monitoring evaluation, and the industrial hygienist believes much is learned by the fixed samplers, which would not be revealed by mobile samplers attached to workers. Specifically, it is possible to note that a given area is undergoing an upward trend, or that a sudden change in ambient lead concentrations, for example, has occurred. Such information may serve as a warning signal and lead to corrective actions before the situation worsens.

In relation to the measurement of short term concentrations of gases and vapors, it is attractive to use indicating tubes, and although there are many limitations to the use of such tubes, they are becoming more reliable and useful due to the improvement in quality resulting from the NIOSH certification program. It is now possible to use certified tubes and be reasonably confident that the results will fall within the limits permitted by the certifying agency. There is also growing use of the tubes for long-term sampling, whereby the worker wears a device which holds one or more tubes, through which air is drawn at a very low sampling rate for an extended period of time. Providing the appropriate calibration data are available from the supplier or from the user's own laboratory, such sampling may indeed be attractive due to its simplicity and direct read-out. There are still inherent limitations in the use of all indicator tubes, and care should be taken with respect to such variables as the age of the tubes, the presence of interfering substances, sensitivity, and so forth.

Even more attractive as sampling devices are the relatively new units generally referred to as passive samplers, which are designed to be worn as simple badges attached to the worker, and which are thereafter removed and analyzed by some appropriate means in the laboratory. There are at least two such kinds of devices currently on the market, both of which have recently been described (2,3), and which appear to be promising. The first device has been shown to give reliable data for sulfur dioxide and nitrogen dioxide and ought to be applicable to sampling organic vapors also. The second unit is specific for mercury, and in tests performed by NIOSH, proved to be surprisingly accurate for integrated measurements of mercury vapor. Undoubtedly the simplicity of such devices will encourage research efforts to increase their number, validity, and reliability. At present, however, it is probable that results obtained with such devices would not be considered adequate for demonstrating compliance with OSHA standards.

Another type of instrument useful in evaluating occupational exposure to toxic compounds is the continuous monitoring device, which is usually equipped with a recorder and/or alarm to alert those in the area to the presence of a potentially dangerous concentration of some gas or vapor. Such units are commonly found in areas where large quantities of hydrogen cyanide could be evolved, and are also useful in measuring carbon monoxide and other gases which have poor warning properties.

Once the air has been sampled and the substance of interest collected by suitable means, it is usually necessary that analyses be performed in the laboratory; although much analytical work has become routine, there are some problems of current concern. First, the concern with rather uncommon chemicals has challenged the analyst, and frequently it is difficult to devise a method which is suitably sensitive and specific for the chemicals present in the work room air. Another problem is posed by the government standard for "coal tar pitch volatiles," wherein the analysis is conducted for that portion of the sample which is soluble in benzene, rather than for active ingredients such as benzo-a-pyrene which may be responsible for the standard in the first place.

There is an increasing need for the analyst to adopt more sophisticated methods capable of differentiating different valence states of elements like arsenic and chromium. In the case of the proposed chromium standard, not only must the analyst limit analysis to hexavalent chromium, but also the solubility of the compound may be a factor in measuring the hazard. In other instances, a standard may vary if the substance is present as a fume rather than a dust, yet the analytical methodology for making this distinction is almost nonexistent.

A particularly troublesome problem is created when complex organic mixtures like most modern plastics are heated for extrusion or other purposes and thereby release a mixture of gases, vapors, and fumes about which relatively little may be known. The collection and analysis of these products is a subject about which much less is known than is desirable.

Finally, it should be noted that the requirements of modern standards are such that a great number of samples will be taken in the course of several years, and recordkeeping becomes a formidable problem.

It is probably essential that most organizations, particularly the larger ones, devise a system for storing basic air sampling data in such a way that it can be readily retrieved for future interpretation. In general, the data must be stored in at least two ways, the first relating to specific work operations and the second relating to individual workers. Many industrial hygiene organizations have evolved excellent systems and are finding them to be most convenient and useful.

Consideration should also be given to biological monitoring whenever applicable, in the recognition that air sampling is often limited in its ability to predict the true extent of absorption of toxic compounds in the work place. Then it is necessary to confer with medical and nursing personnel concerning the desirability of such employee testing, as well as its implementation. Many substances can be detected in blood, urine, or breath, and it may be useful to look for known metabolites of the substances. Relatively few biochemical determinations are as useful as blood-lead levels, however, and often difficulties will be encountered in interpreting results of sampling.

When the above actions have been taken, ideally the industrial hygienist will possess the information required to make an assessment of the hazard potential for the work operations studied. Depending upon the nature of the substances encountered, he may wish to base his actions primarily upon time-weighted average exposures, which may be compared to existing standards, or he may be concerned with short term concentration peaks for other substances. If the data relate to such well known toxic compounds as carbon monoxide or phenol, the appropriate course of action may be relatively easy to select.

In the simplest cases, whenever federal standards of TLVs are available, they may dictate certain courses of action, or at least serve as the best available guidelines. It is much more difficult to take appropriate action when no such standards exist, and unfortunately there are many instances where exposure to toxic compounds does occur, yet no recommended permissible work place limits are available.

Perhaps the worst possible case is the situation where a variety of complex organic compounds is in use, no standards for any of

them have been proposed, relatively little is known about the effects of exposure to each, and nothing is known of the possible interactions which may occur either in the atmosphere or within subjects exposed to the mixture. In my own experience, such situations are frequently compounded by yet another variable, that of infrequent or sporadic exposure resulting from batch-type operations.

It is impossible to outline the best industrial hygiene approach to such situations, except in the most general manner. In essence, the industrial hygienist is compelled to act as a TLV committee, or NIOSH standard-producing group, and seek by whatever means possible to make a reasonable estimate of what a permissible air standard should be, as well as what other precautions relating to skin absorption, and so forth, should be taken.

It is highly desirable, if not imperative, that all organizations utilizing a number of compounds for which no official or suggested standards are available, designate a committee consisting of personnel from industrial medicine, hygiene, safety, and other involved units to assemble all available information, and to formulate in-house permissible concentrations for the workplace environment. This committee should further be charged with making recommendations concerning the need for more information, when it is apparent there is almost no data base for making the required decisions.

There is another aspect of modern industrial hygiene procedures which has been growing in importance and will certainly continue to become a subject of increasing concern. As noted previously, there are many instances when data simply do not exist to justify the establishment of a given permissible environmental level of a substance. The 1976 edition of the "Registry of Toxic Effects of Chemical Substances," or the "toxic substances list" as it was previously known, contains some information on nearly 22,000 different substances. Presumably any or all of these may be used by some industries, but OSHA standards exist for less than 500 substances, and many of these are not supported by convincing toxicological or epidemiological studies.

The pressure to obtain better data in order to substantiate a given standard or perhaps to refute a proposed standard has

mounted to such an extent that there is a great deal of activity to perform epidemiological studies, usually retrospective, in order that mortality and morbidity findings may be made quickly available. Almost invariably such studies are successful in mobilizing adequate mortality data and possibly even morbidity data but, practically without exception the environmental data will be found wanting. It simply has not been the practice during the preceding decades to routinely sample the work environment in such a way that a large body of data adequate to interpret epidemiological findings is amassed.

It is impossible for the industrial hygienist to create data for the past, of course, but he and the other members of the industrial health team should be examining their own operations for the purpose of determining what sampling data could be useful in establishing the necessary dose-response relationships for substances of importance to the organization. Many examples could be cited, but perhaps the situation with respect to inorganic arsenic is as good an example as possible.

For many years, the permitted exposure to inorganic arsenic was 0.5 mg per cubic meter, until NIOSH recommended in a criteria document issued in 1973 the time-weighted average concentration be lowered to 0.05 mg per cubic meter, or 50 micrograms per cubic meter. Subsequently, evidence released by several industrial arsenic-using companies suggested that some forms of arsenic were carcinogenic, and accordingly, NIOSH revised its recommended standard downward to 2 micrograms per cubic meter in a new criteria document issued in 1975.

Understandably, many industries affected by the new standard were greatly concerned and attempted to mobilize evidence that the proposed standard was far too restrictive. Several major copper smelters were among those most affected by the proposed standard but quickly found themselves in exactly the situation referred to earlier, with inadequate environmental data to support their position. Certain epidemiological studies have shown an increased incidence of cancer in some smelters, and the smelters argue that these cases were the result of greatly elevated exposures in past years.

Although their position may be correct, the smelters are thus far in the position of being unable to present sufficient environmental data to support any apparent threshold of carcinogenic activity. In recent years, however, the tempo of environmental sampling for arsenic has increased greatly, and it is highly probable that it will be possible, in the relatively near future to begin to make reasonable estimates of the apparent threshold of carcinogenicity for arsenic compounds in the workplace.

Unfortunately the long period of time required to produce cancer of occupational origin limits the immediate usefulness of currently acquired data, and this may tend to discourage ambitious sampling programs which could shed substantial light on cancer-exposure relationships. But it is improbable that satisfactory data will be obtained by any other means. Certainly, the industrial hygienist should be encouraged to confer with the epidemiologist regarding his data requirements.

In cases where the toxic compounds are not necessarily suspected of being carcinogenic, studies begun as soon as the industrial hygienist is able to commence them could be valuable in helping to establish no-effect levels and possibly threshold levels. One major chemical company, which has long been noted for the general excellence of its industrial hygiene program, has made it a practice for years to make notations of sensory responses experienced by the industrial hygienist during the course of his sampling and related investigations. The data accumulated over a period of years by several industrial hygienists proved to be very valuable in the formulation of appropriate environmental standards for chlorine, where the principal problem is irritation of the eyes, nose, or throat.

CONTROL

The control of hazards which have been identified and evaluated may be a routine matter which is easily handled by the engineering staff of the organization, or it may be far from routine and entail extremely large expenditures. Certainly, the most common control strategy involves the traditional use of exhaust ventilation, combined with maximum enclosure of the operation. With the advent of ever more stringent standards, however, this approach may not

be adequate for many situations, and it is essential that considerations be given to such measures as process alterations which permit the total separation of the worker and the toxic compounds, usually by total enclosure and automation. For some potent carcinogens, this is already a reality, and for many other toxic compounds it is very likely the only practical means of achieving compliance with the near-zero standards.

Control of exposure to toxic compounds by respiratory protection is the "last resort" approach, which should be required only when engineering control is impossible or extremely impractical. OSHA generally frowns upon the use of respirators of any kind, but there are many situations where the use of a well designed supplied-air respirator, for example, may be the best method of accomplishing the required degree of worker protection.

Regardless of the expected consequences of occupational exposure to a substance, it is apparent the requirements of OSHA and the Toxic Substances Act will inevitably increase the demand for good environmental exposure data for almost all toxic compounds in use by industry. Although the industrial hygienist may deplore the burgeoning need for measurements of levels of exposure, it is highly unlikely that the pressure to obtain such information will decline; rather it will tend to increase with the passage of time.

The industrial hygienist and all the other members of the health/safety team should do everything possible to keep up with the pressures created by legislative demands, and if possible, anticipate those demands and have the answers prepared before the questions are asked.

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