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Threshold Limit Values: Historical Perspectives and Current Practice

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A 1989 Occupational Safety and Health Administration standard mandates that workplace air concentrations be held below new permissible exposure limits for 376 substances. As more than 350 of these limits came from the 1987 list of "Threshold Limit Values" (TLVs), the medical basis of the TLVs is of direct importance to the health of millions of workers. However, the TLV development process has been gravely flawed by lack of scientific rigor, inadequate medical input, and lack of attention to financial conflicts of interest. The adoption by the Occupational Safety and Health Administration of many poorly supported values as permissible exposure limits reflects also the underutilization of industrial medicine in identifying health effects of exposures below the TLVs. It is thus the responsibility of the medical profession to act on the presumption that the TLV permissible exposure limits are unsafe limits until a sound underlying body of medical and scientific literature exists for the substances on the list. It is industry's responsibility to commit itself seriously to medical and exposure monitoring and to begin to remedy the knowledge deficit that exists about the less immediate health effects of most industrial materials.

Before reviewing the subject of occupational exposure limits, certain basic issues bear mention. First, the medical profession has a fundamental importance in the investigation and evaluation of the harmful effects of industrial materials. Second, the necessary medical resources need to be provided by industry to make possible the medical surveillance and care of workers exposed. Third, there is a need to develop and train the profes-

sional resources to meet the needs of the millions of places of employment. The adoption of standards with specified numerical exposure limits accomplishes nothing unless the necessary professional resources are provided to gather and evaluate information on exposures and health effects.

The Occupational Safety and Health Administration (OSHA) Standard for Air Contaminants

In the closing days of the Reagan Administration, OSHA adopted new permissible exposure limits for 376 substances.¹ Virtually all of these limits came from the 1987 list of Threshold Limit Values (TLVs) published by the American Conference of Governmental Industrial Hygienists. Industry is required to be in compliance by September, 1989.

In developing this standard, OSHA disregarded recommendations by the National Institute for Occupational Safety and Health (NIOSH) for stricter limits for 68 specific substances. The idea of adopting the TLVs had been suggested in 1983 by the Synthetic Organic Chemical Manufacturers' Association, and the chemical industry's response to this OSHA rulemaking was unusually favorable (C.B. Mackerron; *Chemical Week* January 25, 1989, and comment from the Dow Chemical Company on OSHA's proposed air contaminants rule [July 1988]). The AFL-CIO and at least 16 industrial parties have gone to court over the standard.

OSHA has recently announced that it is considering additionally requiring medical monitoring and air monitoring in industries where regulated substances are used.

Physicians in industry have good cause, therefore, to wonder how protective the new limits are. In fact, the scientific quality of the process for developing the TLVs has been critically examined, and evidence of "corporate influence" in developing the TLVs has figured in the

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debate over the new OSHA rule. A paper on these issues, published in May 1988, has engendered a lively discussion including more than 20 commentaries by the end of 1988 in the *American Journal of Industrial Medicine*.²

The purpose of this paper is to summarize the critique of the TLVs, referring to data already published as well as presenting information gathered since OSHA proposed its new rule in mid-1988. The material here will be addressed primarily to physicians in industry.

The story begins by recounting how the medical responsibility of relating working conditions and health was in large part assumed by a group of industrial hygienists, the American Conference of Government Industrial Hygienists (ACGIH).

Origins of the TLVs

ACGIH traces its history as a professional organization back to 1938. An ACGIH committee compiled a listing of state government exposure limits for various chemicals in 1942.³ In 1946, ACGIH published its first annual list of recommended "Maximum Allowable Concentrations" (MACs) for 144 substances.⁴ The primary sources for this were ACGIH's 1942 compilation and a 1945 paper by industrial hygienist Warren Cook.

It is interesting to recall what was said of the safety of these limits at the time, in view of later developments. ACGIH said in 1942, "The table is not to be construed as recommended safe concentrations. As if to underline that point, the text went on to say, "The material is presented without comment."³ Cook,⁵ whose paper supplied 118 of the exposure limits adopted, emphasized that his intent was "to provide a handy yardstick to be used as guidance for the routine control of these health hazards—not that compliance with the figures listed would guarantee protection against ill health." Cook went on to advise that maintenance of the limits he suggested should not be considered a substitute for medical monitoring.⁵

By 1946, most state governments had industrial health units, and so did some cities and counties. The MAC values reported by 27 of these agencies were quite variable for some chemicals. For *n*-butanol, the limits varied from 25 to 300 ppm in air, depending on where the workplace was located. For turpentine, the range was 100 to 700 ppm, for methanol, from 100 to 300 ppm, for nitrobenzene, 1 to 5 ppm. On the other hand, there was substantial agreement among the health agencies for many other chemicals.⁶

Up to this time, MACs in use had "on the whole [caused] no serious handicap to industry," according to J. J. Bloomfield, one of the leading industrial hygienists of the US Public Health Service.⁶ However, there was a desire among the government people to harmonize their MACs and thus avoid the health and economic impacts of having divergent conditions for industry.

ACGIH acknowledged in 1946 that no uniform definition of MACs existed, citing three concepts then in use: no safety margin against known health effects, some safety margin against health effects, and protection

from objectionable but not harmful concentrations. ACGIH initially declined to define what its MACs were or to state whether they were limits not to be exceeded for 30 minutes, 1 hour, 8 hours, or longer.⁴ For example, the MAC for chlorine was 5 ppm, which compared unfavorably with 4 ppm recommended by Henderson and Haggard⁷ for 30-minute to 1-hour exposure periods. The 100 ppm MAC for carbon monoxide had been recommended by Henderson and Haggard for several hours.⁸

The 1947 list included 155 MACs. The chairman of the Committee on Threshold Limits, chemist L. T. Fairhall, expressed great confidence that the industrial hygienist was well placed to set health standards: "He is in contact with the individuals exposed and therefore soon learns whether the concentrations measured are causing any injury or complaint."⁹ Up to this point, the five-man TLV committee still did not include one physician member.

In 1948, the MACs were renamed Threshold Limit Values. Despite the very different emphasis of this new nomenclature, the term TLV was not defined at the time of its introduction. The TLV committee noted that "People vary greatly in their response to drugs and toxic substances." To this irremovable obstacle was added the acknowledged difficulty of trying to protect the worker while not imposing an "impossible burden on the manufacturer."¹⁰

In 1953, a preface was added, wherein the TLVs were described as "maximum average concentrations of contaminants to which workers may be exposed for an 8-hour working day (day after day) without injury to health."¹⁰ Both the term used and its definition now promoted the TLVs as health-hazard thresholds for exposure to chemical and mineral substances, many of which were known to have serious, irreversible effects. The TLV committee now sought to offer a guarantee where Cook had explicitly said no guarantee was warranted. Most of the exposure limits on the list were the same values recommended in 1945 by Cook.³ Despite the accompanying preface assertion that the TLVs were based on the best available information, there is no evidence that any review was done or new rationale offered to justify this sweeping disregard for the uncertainties underlying the TLVs.

The TLV committee chairman, industrial hygienist Alan Coleman, used more qualified language at the ACGIH meeting of 1954. He described the TLV as the concentration of a substance that "should cause no significant injury to the health of the large majority of persons" exposed daily.¹¹ The committee itself tempered its description in 1958: "[TLVs] represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect."¹²

Precisely because the TLV committee had taken a very difficult technical, political, and economic problem off the shoulders of state and local agencies, the TLVs were uncritically welcomed as uniform limits across the country. State and local agencies reduced their proportional employment of medical personnel and all but stopped issuing MACs on their own in the early 1950s.

As it became clear that the state and local officials on the TLV committee were not issuing terribly burdensome limits for their local plants to meet, industry adjusted to this state of affairs without protest.

Meanwhile, the commercialization of new chemicals by industry far outstripped the capabilities of a volunteer committee to keep up. As new chemicals were widely introduced by the hundreds, the TLV committee struggled to add to its list less than 10 per year. Revisions of the TLVs, once listed, were fewer still, and it is evident that, after the first few years, the primary focus of the TLV committee was on expanding the list. Until 1962 this responsibility was handled by a committee of only four to eight people.

Many pitfalls of reliance on the TLVs had been anticipated from the time they were launched. W.P. Yant, first President of the American Industrial Hygiene Association, told members of the Industrial Hygiene Foundation that monitored average concentrations of air contaminants would not take account of several factors: peak exposures that could be very harmful, synergistic effects of multiple exposures, and the great increases in respiration rates arising from high levels of physical activity and work in hot environments.¹⁴

Yant also observed that lists of limits gain "prestige and authority through mere copying and repetition." He warned that mandatory requirements, which the TLVs were clearly destined to become, were usually minimum requirements, "representative of the worst permissible conditions." Such requirements, he said, could "stifle progress and freeze endeavor at the established minimum."¹⁴ Yant's apprehensions proved well founded, as the TLV committee fell further behind in its efforts to keep pace with innovation. As the list of TLVs grew longer, more of the limits would tend to be based on reviews and information not updated for years.

British authorities criticized American practice for its heavy emphasis on measurement and reliance on reference limits. Noting that TLVs were almost always amended in the downward direction, "reducing the concentration formerly accepted as safe," United Kingdom factory inspector Bryan Harvey¹⁵ preferred to call them "theoretically allowable maximum concentrations." Medical Inspector of Factories A.I.G. McLaughlin¹⁶ derided the very idea of threshold limits as reflecting an assumption that "man is a standardised machine." The indoctrination of American industry and professionals with a preoccupation with taking samples and designing controls to meet reference exposure limits was in turn seen as the basis of another serious shortcoming: a peculiarly American tendency to consider substitution of dangerous materials as the last line of approach to health hazard control instead of the first.¹⁵

Industrial physicians in the United States were also dismayed at the growing acceptance of the TLVs, issued by a committee dominated by industrial hygiene engineers, chemists, and toxicologists. Initially, not a single physician was on the TLV committee; at most, physicians comprised only a small minority of the committee members. Never had the chairman of the TLV committee been a physician (this would not happen until 1985). At a 1952 meeting of leaders of the Industrial Medical

Association, clinician Frank Prince said "[M]ost of the [TLVs] are picked out of a hat. 95 percent are on the basis of animal experiments only, incorporated into state codes, and we are faced with ridiculous standards. Is there a doctor among the group that puts out these standards?"¹⁷

After all, what industrial hygienist sees the workers' health status the way the plant doctor does? What toxicologist is intimate enough with his rats to learn whether they feel pain or are suffering from reduced mental acuity? What did these government engineers, chemists, and toxicologists read or know of the medical literature, even just what is imparted in *JAMA* or the *Lancet*? It would have been malpractice if a council of doctors had prescribed such a list of exposures as approved for consumption by all the workers in the country.

ACGIH nonetheless went on to make the essentially medical evaluations on which new TLVs were based. The industrial physicians' group did not undertake the task of either publicly criticizing the TLVs or proposing its own workplace exposure limits. Only occasionally did individual industrial physicians pass on information to the TLV committee through the 1950s and 1960s.

Led by toxicologist Herbert Stokinger of the Public Health Service, the TLV committee expanded its membership and output in the early 1960s. ACGIH also published for the first time a volume entitled *Documentation of Threshold Limit Values*,¹⁸ where the basis for about 250 TLVs was stated, with references in the space of 112 pages.

Stokinger approached the Manufacturing Chemists Association (now Chemical Manufacturers Association) for increased input from member firms starting in 1964. This met with limited response. The companies had no statutory duty to disclose new knowledge about chemicals used in general industry before the passage of the Toxic Substances Control Act in 1976. In the years before the Occupational Safety and Health Act (1970), regulation of workplace health hazards by the states was minimal, and manufacturers were about the only parties capable of knowing what the exposures were in their plants and whether there were adverse medical consequences. ACGIH's annually republished claim that the TLVs were based on the "best available" information thus sidestepped the reality that the TLV committee was left begging for data. A committee of the Industrial Medical Association acknowledged that unpublished data was in the possession of companies that could contribute to the establishment of "realistic TLVs."¹⁸

Corporate Influence on the TLVs

The recommendations of corporate officials and consultants were given great weight by TLV Chairman Stokinger. Massachusetts health official and longtime TLV committee member Hervey Elkins complained in a letter to fellow committee member William Frederick in 1966: "It annoys me no end, that any action that could possibly adversely affect a certain chemical company is

immediately objected to by a consultant to said company, and the objection is always accepted by the Chairman " The companies themselves, individually and under the auspices of such groups as the Industrial Hygiene Foundation, also had periodic meetings with members of the TLV committee and communicated their concerns both orally and in writing.

Just as some corporate communications to the TLV committee delayed or prevented action, other unpublished information was accepted as the basis for setting TLVs. The growing reliance on unpublished corporate communications, some of which were phone calls and most of which do not survive in written form today, is reflected in the *Documentation*.²⁰

By 1986, unpublished corporate communications were important in supporting TLVs for 104 substances out of less than 600 listed in the *Documentation* (5th ed). For twenty-five of these key communications from corporate employees (out of 104), the corporate affiliations of the correspondents were not stated in the *Documentation*. Of the 104, the 37 cases of unpublished "industrial experience" reflect a pattern of uncritical acceptance of assertions from financially interested parties, based on scant data of poor quality. These assertions, absent explanations of materials and methods used, would never be accepted for publication in medical or other scientific literature. Moreover, they include many evaluations of a medical nature that were reported by industrial hygienists and other nonphysicians.²⁰

Some had expected that the story of the TLVs would have ended with the adoption by OSHA of most of the 1968 TLVs as its first set of exposure limits. Congress established and funded NIOSH for purposes of conducting research and making recommendations to OSHA for health standards. But the TLV committee not only remained as active as ever after 1970, it even permitted full-time employees of chemical companies to become centrally involved in the development of the TLVs.

The participation of industry representatives on the TLV committee began with the addition of Dow toxicologists V K Rowe and Theodore Torkelson as "liaison members" in 1970. These men were assigned responsibility for developing "documentations" on which new or revised TLVs would be based. The chemicals assigned to them initially were all Dow products (2,4,5-T, vinyl chloride, ethylene glycol, methyl bromide, and propylene glycol methyl ether). No objection was evidently made over the fact that many of the chemicals assigned to these employees of Dow and industrial hygienist James Morgan of DuPont (starting in 1972) were products marketed by the firms that employed them. The chemical assignments of these individuals were regularly recorded in the minutes of the TLV committee, although publicly it was stated that these "consultants" did not actually vote on adoption of TLVs.²¹

Perhaps because the corporate representatives were paid for their work on the TLV committee and provided with the ample resources and support of their employers, they were among the most active contributors to the TLVs. TLV committee minutes and other records show that Torkelson, individually and as chairman of key subcommittees, was assigned at least 30 of Dow's

halogenated solvents, pesticides, and other industrial chemical products between 1970 and 1988 (since 1977 including perchloroethylene, trichloroethylene, 1,3-dichloropropene, divinylbenzenes, carbon tetrachloride, chlorine, propylene dichloride, ethylene diamine, methylene chloride, and acrylamide). Similarly, Morgan and his successor Gerald Kennedy of DuPont obtained the task of documenting many DuPont pesticides, chlorofluorocarbons, and other products (since 1977, including hydrogen cyanide, acrylonitrile, hexafluoroacetone, *p*-nitrochlorobenzene, trichlorotrifluoroethane, and dimethylformamide).²

Dr Georg Kimmerle has been listed in TLV booklets since 1981 simply as "German MAK Commission liaison." He is a physician employed by the German chemical producer, Bayer, whose US subsidiary Mobay makes pesticides, isocyanates, and other chemicals. Shortly after joining the TLV committee, Kimmerle was primarily responsible for the decision to double the TLV for one Mobay pesticide (fenthion). He then drafted documentations for new TLVs for three other pesticides made in the US solely by Mobay (fenamiphos, metribuzin, and sulprofos). The other five chemicals recorded as assigned to Kimmerle (amitrole, thiram, xylydine, perchloromethyl mercaptan, and phenylene diamine) are produced by Bayer in West Germany. Kimmerle's handling of TLV committee work, unlike his duties with the German MAK (Maximum Workplace Concentration) Commission, were not required to be handled as a confidential, separate matter from his job at Bayer.

In all, corporate representatives were given primary responsibility for developing TLVs on more than 100 substances between 1970 and 1988, including at least 36 classified as carcinogens by official bodies. (Complete information on the chemical assignments is not even available from ACGIH.) There is no question that the economic impact of the TLVs on the chemical industry, generally and on Dow, DuPont, and Bayer in particular, has been enormous. There seems no reason to doubt that chemical industry employees working on the TLV committee were implementing corporate policies of their firms. This view is consistent with Dow's recommendations to OSHA to adopt the TLVs instead of stricter NIOSH recommendations for seven Dow products, at least six of which had been handled by Torkelson on the TLV committee.⁵

Industry employees aside, practically nothing has been disclosed about the documentations assigned to committee members who had part-time consulting relationships with chemical producers. ACGIH has never required members of the TLV committee who do corporate consulting to either disclose these business connections or excuse themselves from development of TLVs on chemicals of importance to their clients. The TLV booklets have listed such persons only by affiliations they had with universities.

TLV committee minutes fleetingly mention meetings of the committee and its subcommittees with dozens of representatives of companies and trade associations. Nothing in writing relating to most, if not all, of these meetings is in the chemical files at ACGIH. Robert Spirtas, a member of the committee since 1981, wrote

of his impression of these encounters in a 1987 letter to TLV Chairman E. Mastromatteo: "[P]resentations by outside groups have, in my experience, always been allied with the management point of view. The majority of the presentations have been personal interpretations of the published literature. In my opinion, these presentations have been attempts to lobby the committee with very little new data." This state of affairs led ACGIH Secretary-Treasurer Philip Bierbaum to urge, in a 1988 memorandum to the ACGIH Board, that no presentations by outside groups to committee members be allowed unless they are publicly announced and open to the public.

As of late 1988, the TLV committee would not even permit interested scientists to attend its meetings as observers. Only after OSHA had proposed to adopt hundreds of the TLVs in 1988 did ACGIH allow researchers to examine relevant ACGIH files (eg, recent TLV committee minutes).

The TLV committee has stoutly refused to publicly disclose members' paid sources of corporate consulting work. This might be extensive, as the present 22-member committee includes only six full-time government employees. The TLV committee has also resisted recommendations by its only labor representative and members of the ACGIH Board that industry employee members of the committee be precluded from drafting TLV documentations.

Although some reforms may finally be instituted in 1989, the many TLVs just adopted as OSHA standards are a legacy of an earlier era. Former NIOSH director John Finklea has remarked that the TLVs were "the result of a process that would currently be viewed as seriously flawed."²²

Medical Inadequacy of the TLVs

The information base upon which the TLVs were developed was severely limited. For standards intended for a potential lifetime of exposure, chronic data are critical. However, for at least 90% of the TLV chemicals, sufficient data on long-term effects are unavailable, either from animal studies or studies of industrial workers with long-term exposure to known concentrations of the substances.

The very concept of a *daily average* exposure limit has been attacked as being inconsistent with what is known about toxicity, and evidently originating more from economic than scientific considerations.^{23, 24} Atherley's analysis concluded that the time-weighted average index "cannot be viewed as a scientific idea underpinned by either empirical evidence or plausible scientific hypothesis."²⁴ In view of this, the TLV committee's deletion in 1984 to 1986 of most of the short-term exposure limits was particularly harmful. ("STELs" for nearly 200 substances were dropped prior to OSHA's adoption of the TLVs.)

The TLV committee's heavy reliance on animal data (mostly acute and subacute toxicity studies) raises a number of unavoidable problems. One cannot elicit a medical history from an animal, and symptom data can be missed that could be severe enough in a human to

interfere with productive function at work. In addition, the animal data gathered were very limited in scope as well as duration. Typically, no study was done of neurologic and neurobehavioral function beyond meager observations of animal behavior such as lethargy, fighting, etc. Thus, animal studies are unable to evaluate cognitive changes such as we now know can occur from exposure to many solvents and other chemicals.

Animal studies also have not included an evaluation for pulmonary function, despite the fact that many chemicals are irritants and/or chemical allergens, and repeated exposure to such agents could well reduce pulmonary function, nor was immunologic function evaluated for the vast majority of chemicals. Endocrine function was at best evaluated by an occasional blood glucose test, typically ignoring the potential for endocrine alterations in other organs. Animal studies often did include information on the appearance of many but not all organs at death by gross and light microscopic analysis. However useful structural information is though, it is not a substitute for evaluating the function of organs.

Another shortcoming of the TLVs was the frequent failure to use information that was available. For example, no systematic literature search was done in preparing documentations on hundreds of chemicals. References used are often very dated, and more recent information is often missing. Information in the international medical literature does not appear to have been reviewed for the vast majority of chemicals. In fact, little reference is made to the basic US medical literature in the TLV documentation. Thus, contrary to the TLV booklet's persistent claim, the TLVs are not "based on the best available information."

The medical inadequacy of the TLVs is evident from a review of four occupational medicine journals since the start of 1987 (Table). From this limited sampling, it would appear that further evidence of harm at and below the TLVs appears in the literature almost monthly. This review did not include industrial hygiene, toxicology, and general medical journals. Other scientists are encouraged to review these for sub-TLV effects.

The development of TLVs and evaluation of relevant scientific literature have mainly been done by industrial hygienists and other nonphysicians. Although industrial hygienists are vital to developing control strategies for chemicals, most lack training in the biomedical sciences to interpret health effects data reliably and independently. Yet this is exactly what they had to do as volunteers on the TLV committee. Copies of reviewed articles were generally not provided to the entire committee; the sole responsibility for accurate interpretation of the articles typically fell to the committee member assigned each chemical. The result was a list of exposure limits produced almost entirely by hygienists, chemists, and toxicologists, most of whom lacked the necessary training, let alone clinical experience with humans.

Toxic Torts and the TLVs

It is ironic that doctors may now be asked to confer legitimacy-in-retrospect on the TLVs.

TABLE
Health Effects at and below the TLVs*

Substance	Effects Reported/Exposure	TLV	Ref
Acetone	Neurobehavioral performance effects after 4 h at 250 ppm	750 ppm	25
Benzene	Bone marrow changes, leukemia, at or below 1 ppm	10 ppm	26 27
Beryllium	Respiratory sensitization below 2 µg/m ³	2 µg/m ³	28
Cadmium	Changes in renal function at 0.007–0.039 mg/m ³	0.05 mg/m ³	29
	Changes in renal function at 0.003 mg/m ³		30
	Changes in renal function at cumulative exposures equal to 20–22 yr at 0.05 mg/m ³		31
2-Ethoxyethanol and 2-Methoxyethanol	Lowered sperm counts and reduced red and white (granulocytes) blood cell counts at combined exposure to 9.9 mg/m ³ 2-EE and 2.6 mg/m ³ 2-ME	19 mg/m ³ (2-EE) 16 mg/m ³ (2-ME)	32 33
Ethylene diamine	Respiratory sensitization at 1–10 ppm	10 ppm	34
Ethylene oxide	Increase in sister chromatid exchanges in lymphocytes at 0.35 ppm	1 ppm	35
Formaldehyde	Respiratory cancer allowing for 10 yr latency, 0.1–1 ppm	1 ppm (1.5 mg/m ³)	36
	Pathologic changes in nasal mucosa at 0.1–1.1 mg/m ³		37
Glutaraldehyde	Increased respiratory symptoms and headache below 0.04 mg/m ³	0.7 mg/m ³	38
Lead (naphthenate)	Blood lead concentrations over 60 µg/dL, mean ZPP† of 265 µg/dL, at 0.96 µg/m ³	150 µg/m ³	39
Manganese dust (inorganic)	Fatigue, trembling, tinnitus, irritability at 1 mg/m ³	5 mg/m ³	40
Mercury vapor	EEG changes at 25 µg/m ³	50 µg/m ³	41
Methyl chloroform (1,1,1-trichloroethane)	Behavioral performance deficits with 3 h at 175 ppm and 350 ppm	350 ppm	42
	Decreased DNA concentrations in the brains of gerbils after continuous exposure to 70 ppm for 3 mos		43
Oil mist, mineral	Cross-shift decline in 1-sec FEV at 0.2 mg/m ³	5 mg/m ³	44
Silica	Lung scarring in bricklayers exposed to dust (2.1% free silica) 0.5–2.0 mg/m ³	2 mg/m ³	45
Styrene	Occupational asthma at 62.7 mg/m ³	215 mg/m ³	46
Sulfur dioxide	Bronchoconstriction among asthmatics after 3–5 min at 0.5 ppm	5 ppm†	47
Sulfuric acid mist	Laryngeal cancer at 0.2 mg/m ³	1 mg/m ³	48
Toluene	Neurobehavioral effects in rats exposed 20 min to 125 ppm	100 ppm 150 ppm†	49
	Impairment in human performance after 6–6.5 h at 100 ppm		50
	Increased fatigue, short-term memory changes, reduced concentration at 11.5 ppm and 41.8 ppm		51
	Neurobehavioral changes (visual vigilance) after 4 h at 100 ppm		52
Toluene diisocyanate	Asthma developed within 1 yr in 9 workers at 0.002 ppm	0.005 ppm	53
Triethylamine	Blue haze (foggy vision), corneal edema, eye irritation at 18 mg/m ³	40 mg/m ³	54
Zinc oxide fume	Lung function changes in guinea pigs exposed 3 h on 6 consecutive days to 5 mg/m ³	5 mg/m ³	55

* This table was compiled from review of the contents of 33 months (January 1987 to September 1989) of 4 journals: *Journal of Occupational Medicine*, *American Journal of Industrial Medicine*, *Scandinavian Journal of Work Environment and Health*, and *British Journal of Industrial Medicine*.

† ZPP, Zinc protoporphyrin.

‡ Short-term exposure limit.

An increasing number of persons are appearing before the courts with conditions medically attributed to chemical exposures. The courts are interested in knowing the state of medical knowledge when these people's exposures to chemical products and wastes occurred. A rationale often used to parry charges of negligence and assessment of liability is known as the "TLV defense." This amounts to: "We thought that the exposures here would be below the TLVs, and we also thought the TLVs were safe, so what happened is not our fault."

But although those in other professions may say, "we

thought the TLVs were safe and sound," it is the opinion of the medical profession (i.e., *not* the medical opinion of the industrial hygiene profession) that is most often sought to test such claims today. Consequently, doctors may be asked to appraise the TLV for one or more chemicals, the TLVs in general, and possibly even the TLV committee, too.

It is hard enough to look back on the withholding of medical expertise and medical knowledge that left so much to the TLV committee for so long. But it is professionally humiliating when doctors are asked to

dignify the medical stature and safety of guidelines that were never really a product of industrial medicine. Lawyers defending chemical liability cases may find that the TLV defense is easier for them to raise in an opening argument than it is to support with credible medical testimony.

Alternatives to the TLVs

There is an urgent need to compile the information that is available but has been ignored in the TLV development process. For example, the New Jersey Department of Health recently utilized chronic health effects data from the Environmental Protection Agency known as the Integrated Risk Information System (IRIS) data base. Workday air concentrations were calculated for noncarcinogens and carcinogens, reportedly corresponding to no risk of chronic health effects or (for carcinogens) a one-in-a-million lifetime risk of cancer. The resulting exposure limits, even for noncarcinogens, were markedly lower than the TLVs, not infrequently by 3 or more orders of magnitude (R. T. Zagraniski, 1988 testimony of the NJ Department of Health at informal hearings on OSHA's proposal to update permissible exposure limits for toxic substances). IRIS data exist on many more chemicals and could be used to supplement our understanding.

Further use needs to be made of the international literature, particularly the industrialized countries. Much information on chemical effects is available in English from the Scandinavian countries. In addition, the Soviet Union has exposure limits on more than 1400 chemicals. These limits were reportedly developed to prevent physiologic alteration, not just clinical disease. Critics of the Soviet exposure limits have sometimes raised a separate presumption that the Soviets in practice follow less stringent limits. But the medical issue is not the state of Soviet engineering practice. Physicians need to have as many data as possible on long-term effects of chemicals to understand what levels could cause harm. Philosophic and political differences have not prevented scientific cooperation in other health-related areas, and international relations now offer hope for expanded USA-USSR contact on matters of importance in industrial medicine.

Exposed workers themselves are a potentially vast source of data. The US experience in occupational health is that medical and environmental monitoring that is not legally required is often not conducted. We are thus missing an enormous amount of potentially useful health-effects data on early functional changes in workers. OSHA's expected medical and air monitoring standards may soon help stimulate industry to generate this dose-response data. However, doctors should not wait for legally mandated monitoring to begin to conduct medical evaluations for potential health effects below the TLVs.

Industry needs to provide adequate resources to allow physicians to visit workplace areas regularly, to monitor all exposed workers medically, and to update their knowledge about toxicologic effects regularly. Doctors

need adequate computer and other literature access for all substances used, released, and produced in the workplace.

Doctors also need to be provided with sufficient time to do a thorough "review of systems." Experience has shown that a great deal of knowledge on chemical health hazards is not in the books, and clusters of adverse effects can be clinically identified sometimes before one of our busy medical colleagues has gotten the problem into print. Clinical cases are frequently the first evidence of occupational disease phenomena, and the patients themselves are an indispensable source of information. With the deficiency of published literature on the chronic effects of most chemicals in use, the need for doctors to take the time to listen to patients is underscored. Occupational medicine is a demanding field, and a full evaluation of a single person with illness potentially related to chemical exposure can take several hours.

Much better use can be made of industrial nurses, especially in small plants, where it is nurses who are the first to see problems and hear workers' health complaints. Industrial nurses and physician assistants, working with physicians, are capable of playing a more sophisticated role in occupational disease assessment than they have been offered in the past. To be most effective, however, these professionals will need to develop additional skills in occupational disease recognition. For example, they will require further training regarding the toxic effects of chemicals, taking medical and occupational exposure histories, and conducting physical examinations. Their preliminary assessments can then be useful in a team approach, working with the physician.

Industrial hygienists can expand their reconnaissance capability far beyond the generation of numbers on exposure levels. Industrial hygienists, as well as nurses and worker health and safety representatives, need specific training on the toxic effects of chemicals on the body and on how to interview workers for health effects in the intervals between medical monitoring. These health effects interviews, although not a substitute for medical evaluation, can nonetheless assist in the early detection of effects from irritants, sensitizers, and nervous system toxins.

The New Jersey Department of Health is developing a Guide to Workplace Inspection that could facilitate this process. That agency's Hazardous Substance Fact Sheets, now available for about 1000 chemicals, include target-organ toxicity information that can help to focus workplace health-effects interviews.

Because the TLVs lack scientific validity, the role of air monitoring should be a different one. A specific air concentration should never be relied upon as indicating safety. Rather, air monitoring should be used to assess the effectiveness of controls. In addition, because at this time there are no known safe exposure levels, physicians as part of the management team should insist on controls that reduce all exposures to the *maximum extent technically feasible*. To advocate a lesser degree of protection would violate the dictum to "do no harm."

Similarly, workplace inspectors may be better off not using the TLV booklet as now written, because of the misleading assertions stated in its preface. These inaccurate claims ("based on the best available information," "nearly all workers may be repeatedly exposed day after day without adverse effect") provide a false sense of security to nonmedical personnel. Unless such claims are deleted from TLV booklets, industrial physicians would be prudent to instead obtain or encourage development of other sources of information.

Despite laws and regulations giving workers the right to know, most hazard communication training programs are general and prepackaged, and do not address the specific toxic effects of the substances used in the workplace. If workers are not properly informed about such dangers, they will not be prepared to alert the medical department when early symptoms develop. Industrial physicians should ensure that all hazard communication training fulfills the legal requirement to include hazards of the specific chemicals used. The New Jersey Hazardous Substance Factsheets are particularly useful in this regard, as they discuss early symptoms and effects in lay English that the worker and supervisor can understand.

Of course, it is primarily industry's responsibility to provide and encourage adequate, coordinated occupational health programs. Just as management provides engineers with flow charts to monitor the industrial process, doctors need to be informed about the materials used and created in every department. It is management's responsibility to encourage cooperation between health professionals, to provide the resources and a framework for monitoring exposures and health of workers, and to grant industrial physicians the authority to fulfill their professional obligations to the people at work. Industrial physicians will not be able to do their job well unless and until industry respects the importance of industrial medicine and makes the commitment to prevent, not ignore, occupational diseases.

The judgment of how much exposure can cause disease in humans is ultimately a medical decision. Industrial physicians, as a profession and through the American College of Occupational Medicine, have the obligation to step forward and assert their responsibilities in assessing health hazards in industry. In fact, to not do so could be viewed as malpractice by some. Workers have been ill served by having critical decisions about their health delegated to engineers carrying TLV booklets.

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