Scand J Work Environ Health 1977;3(1):1-15

<https://doi.org/10.5271/sjweh.2796>

Issue date: Mar 1977

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The following articles refer to this text: [1977;3\(3\):160](#);

[1977;3\(3\):160-162](#)

Key terms: [comparison](#); [health standard](#); [international aspect](#); [international comparison](#); [maximum allowable concentration](#); [occupational health standard](#); [occupational standard](#); [sanitary norm](#); [threshold limit value](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/847426

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Occupational health standards

An international comparison¹

by BO HOLMBERG, Ph.D., and MARGARETA WINELL, Ph.D.²

HOLMBERG, B. and WINELL, M. Occupational health standards: An international comparison. *Scand. j. work environ. & health* 3 (1977) 1—15. The background for establishing standards for toxic agents is reviewed, and the standards of 14 different countries, including Sweden, are compared with special reference to criteria and organizational aspects. The differences among countries in the numerical limit values for toxic substances are largely due to differences in definitions, biomedical criteria, technical feasibility and sociopolitical judgements.

Key words: international aspects, maximum allowable concentrations, occupational standards, sanitary norms, threshold limit values.

Industrial development has created occupational hazards, e.g., accident risks, radiation, climate, noise and other vibration, as well as chemical substances or products which, at sufficient concentrations, can have reversible or irreversible effects upon a living organism. Safety can be achieved for the individual worker if the process or the chemical substance is abandoned or, alternatively, if the process is isolated from the worker (e.g., by incapsulation, distant maneuvers, automatization). When such action is not possible, occupational health standards, i.e., concentrations which under normal circumstances do not cause injury, may be set up.

The concept of occupational health standards includes the assumption that a threshold level for hazardous influence and thus a zero effect level exists for each substance or factor (14, 15, 16). However, as regards carcinogens and allergens, much debate has centered around the question of whether zero effect levels exist at all or are, with a reasonable margin of safety, possible to determine (32, 46, 47).

Occupational health standards for some air pollutants seem to have already been used in the Soviet Union during the 1920s (45). Such standards were first published in the form of a list in 1933 (68). This list included 14 substances. Four years later the state of Massachusetts published the first American list (10), and in 1938 Germany followed suite by issuing occupational health standards for a number of organic solvents (28). Systematic work in the field of occupational health standards seems to have been started in West Germany (Federal Republic of Germany) during the 50s (17). In Sweden the first list was published in 1969 (6) by the then

¹ This review is in part an extended version of a Swedish report (no. 13, 1976) published in the series *Arbete och Hälsa*.

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The term maximum allowable concentration (MAC), coined by the American Standards Association, has become the most commonly used term in international literature even though its legal status differs from country to country. Maximum allowable concentrations of air pollutants are called *hygieniska gränsvärden* (hygienic limit values) in Sweden, *threshold limit values* (TLVs) or *occupational safety and health standards* in the United States, *Maximale Arbeitsplatzkonzentrationen* (MAK) in West Germany, and, in Anglo-Saxon terms, *sanitary norms* or *maximum allowable concentrations* (MACs) in the Soviet Union or, when translated by the Russians themselves, *maximum permissible concentrations* (MPCs).

Occupational health standards for air pollutants concern aerosols, gases and vapors. The values can be expressed in milligrams per cubic meter of air, in the number of particles per volume unit of air or in parts per million (i.e., cubic centimeters of gas or vapor of the substance per cubic meter of air at 25°C, 760 mm Hg). The values state the concentration of the substance in the inhaled air.

Numerous chemical compounds can penetrate intact skin and thereby reach concentrations in the body that are high enough to induce toxic effects. Such substances are designated by a special symbol in several countries, as are substances which are sensibilizing upon repeated skin contact or inhalation.

During the last few years occupational health standards for physical and climate factors have also been introduced in several countries. The biological effect of ionizing radiation has been studied for several decades. Studies on the dose-response relationship of such radiation have resulted in the establishment of accepted doses per time unit for different types of radiation. Interest is also being focused on other physical agents in the work environment. For ultraviolet radiation, laser beams, microwaves, noise, and heat stress, occupational health standards have been established in several countries.

THE ORIGIN AND EXTENT OF OCCUPATIONAL HEALTH STANDARDS

The United States

The American Conference of Governmental Industrial Hygienists (ACGIH) has published a list of occupational health standards annually since 1947 (2). Their standards are called threshold limit values. ACGIH is a voluntary national association of scientists and hygienists within the occupational health sciences. The association has also accepted members from other countries. To apply for membership, one must have a letter of recommendation from two members. The underlying bases of the TLVs are scrutinized by an elected committee within ACGIH, the TLV Airborne Contaminants Committee, which in 1975 had 17 members including the secretary and the chairman. The TLVs are recommended values (i.e., they are without legal status) and the list is protected by copyright. Therefore the TLV list of ACGIH has to be used in its entirety when adopted by other countries; parts of the text or substances cannot be selected, nor can changes be introduced, without special permission.

The TLVs for air contaminants cover around 500 substances and are time-weighted averages or ceiling values. Time-weighted averages are mean values for an 8-h exposure. These values may be exceeded for short periods, but such peaks should be compensated by corresponding lower exposures. Different excursion factors are specified for different TLVs. The ceiling values are not to be exceeded under any circumstances.

Appended to the TLV list is a special list of 24 carcinogenic substances, which in 1975 were divided into three different classes, human carcinogens with or without TLVs and industrial substances suspected to have a carcinogenic potential for man. The last class includes substances which have induced cancer in correctly designed animal experiments or which have been shown to be associated with an elevated risk for cancer in limited epidemiologic studies.

Another appendix to the TLV list is a list of tentative values for certain substances not previously included in the TLV list, but intended for inclusion, and also substances already listed but whose values are currently under proposal for change. The tentative values are to be regarded as test values during a period of two years. Should no serious arguments be raised against the values during that time, they can be accepted by the committee and placed in the regular list.

For physical agents, ACGIH has established TLVs, although the TLV for ionizing radiation is officially established by a federal authority, the Bureau of Standards, U.S. Department of Commerce. For ultraviolet radiation ACGIH recommends TLVs for different wavelengths. These values are also recommended as applicable to sun radiation. In order to protect skin and eyes against injury by laser beams, ACGIH has also set up TLVs for different types of such radiation. Exposure to radiation from microwaves is regulated by average levels for energy density and exposure time. Noise is among the physical agents treated and is regulated by time limits for exposure at different levels [dB(A)]. A special committee for physical agents has proposed the introduction of a heat index which would regulate the work load and time for different heat loads.

The TLV list was the most commonly used list in the United States for a long-time. In 1970, the United States passed a work environment act, Williams-Steiger Occupational Safety and Health Act (40). The American supervising authority, the Occupational Safety and Health Administration (OSHA), under the Department of Labor, is responsible for the work environment and publishes the official federal list of occupational health standards ("Occupational Safety and Health Standards") in the *Federal Register* (42) together with other instructions and regulations for the work environment. The federal OSHA list includes approximately 280 substances and has a higher legal status than the TLV list. Emergency temporary standards, which are in force for 6 months only (41), can be established for certain compounds should newly detected, serious health hazards be suspected as being

caused by earlier exposures to these compounds.

The list of occupational health standards compiled by OSHA is also published by the National Institute for Occupational Safety and Health (NIOSH) in the *Registry of Toxic Effects of Chemical Substances* (the so-called Toxic Substances List) (36). The standards are time-weighted averages for an 8-h workday and/or ceiling values. The great majority of the OSHA standards are identical to the TLVs, although they were adopted with a time lag of a couple of years. Accepted peak values related to a certain time interval have also been designated for some compounds (e.g., benzene, carbon disulfide, formaldehyde, methyl chloride, styrene). These peak values originate from standards published by the American National Standards Institute (ANSI) (44). OSHA has also published special standards for asbestos (37), vinyl chloride (38), and 14 other carcinogenic substances (39). Asbestos and vinyl chloride have been assigned numerical values; in other words, in these standards they have an effect level that is somewhat above zero. No numerical values are given for permissible exposure to the other carcinogenic substances; all exposure should be prohibited. The proper procedures for handling, as well as the technical and medical supervision of the exposure, may be specified for a carcinogen. The detailed regulation for the handling of these compounds supplies perhaps the most important tool for controlling the exposure.

NIOSH is the American authority responsible for the evaluation of occupational health hazards and their technical control. NIOSH, under the Department of Health, Education and Welfare, works out or delegates the preparation of criteria for a recommended standard [e.g., for ultraviolet radiation (34) and ammonia (35)], which are extensive surveys and evaluations of the occupational medical and technical hygienic literature on the subject. These criteria documents, which ultimately propose an occupational health standard for the exposure, are subjected to highly formal scrutiny. The first examination includes a hearing, in which the data and the recommended value are discussed, and

usually attacked, by experts representing industrial interests and by the authors of the document. The next step is an examination made by occupational scientists chosen with reference to their personal experience, and irrespective of their professional ties.

The last step is an examination of the document and the collected criticism or support of it by members of professional associations as, for instance, the Society of Toxicology, the American Hygiene Association, the American Conference of Governmental Industrial Hygienists, the American Academy of Industrial Hygiene, the American Academy of Occupational Medicine, etc. Scientists who partake in the preparation of the document or in a given step of the examination are not permitted to participate in any subsequent step of the process. The final document is revised by the head of NIOSH, who forwards the material including the proposal for the occupational health standard, to OSHA, which in turn can accept or refuse the proposal.

The Soviet Union

A scientific committee for the establishment of maximum permissible concentrations of toxic substances in the work environment is appointed by the Soviet government. The task of the committee is to examine all data and to recommend provisional values to the Ministry of Health. The Central Trade Unions are given a chance to comment on the values while they are still in the form of a draft. Once established, these values are the legal norm throughout the Soviet Union. The aim is to publish a new list of occupational health standards every year. The list presently includes 530 chemical substances (72). In contrast to the American list, the Soviet list gives no time-weighted averages. All values are MPCs and are therefore comparable to the American ceiling values. The MPCs must be taken into consideration during the planning of new industries and processes. Special occupational health standards for short-time exposures (30 min) are presently under discussion.

Czechoslovakia

In Czechoslovakia occupational health standards are established by a permanent commission which has eight members, six being scientists within the field of occupational health sciences, one a scientist from the field of organic chemical synthesis and one a representative from the Department of Health and Welfare. The commission, appointed by the chief hygienist of Czechoslovakia, is an advisory body which submits a proposal to the Ministry of Health and Welfare and to interested parties. The list of occupational standards is published irregularly, the present one dating from 1969 and including around 70 compounds (8). The values are time-weighted averages (mean MAC) together with maximum permissible peaks (peak MAC) which are to be permitted for short-time periods. The peak values are correlated to the time-weighted averages, which in turn refer to one work shift. The occupational standards of Czechoslovakia have a high legal status.

West Germany

A commission on hazardous compounds in the work environment (Kommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe) is appointed by the German Scientific Council (Deutsche Forschungsgemeinschaft). There are two working groups within this commission, one for particles and one for other air contaminants. In 1975 the two groups had 7 and 12 members, respectively (18). The working group on particles is composed of five scientists, specialists in dust and silicosis, from universities and independent institutes and two delegates from the Coal Mining Association. The working group on other air contaminants consists of eight scientists in toxicology and occupational health sciences who are employed by industrial enterprises and four university scientists who are also specialists in toxicology, one of whom is the chairman of the commission. The whole commission consists of 33 members and 6 permanent advisers.

The West German list of occupational standards is published annually and comprises around 370 compounds (52). The

values are generally time-weighted averages for an 8-h workday. They are not legally binding. Skin penetrating and sensibilizing substances are given special symbols. In a special list of carcinogens can be found one group of compounds shown to be carcinogenic in man, as well as another group of compounds shown to be carcinogenic in animals. A third group comprises chemicals suspected of carcinogenic activity. The human carcinogens, including benzene, are not given any standards, in contrast to more than half of the experimental carcinogens.

East Germany

The list of occupational standards (*zulässige Normen*) in East Germany (German Democratic Republic) is established by the Bureau of Standards within the Ministry of Health and Welfare, Berlin. The present list, published in 1972, includes around 180 substances (33). Two types of values are given for each chemical compound, a time-weighted average for 8.75 h and a ceiling value, which is defined as a time-weighted average for 30 min. Around two-thirds of the compounds have different values for short-term and long-term exposures. East Germany has also set up norms for physical and ergonomic factors. The East German list of occupational standards has a high legal status.

Sweden

The first Swedish list of recommended occupational standards was published in 1969 (6) by a working group consisting of 15 members. Seven of these members were from the then existing National Institute of Occupational Medicine in Stockholm. The other eight members came from the Board of Social Affairs, the National Board of Occupational Safety and Health, different clinics of occupational medicine, the Swedish Confederation of Trade Unions (*Landsorganisationen*) and the Swedish Employers' Confederation (*Arbetsgivareföreningen*). The working group submitted its proposal, including an introductory text and different values, to the National Board of Occupational Safety

and Health, which, after criticizing it, returned it to the decision-making body, the National Institute of Occupational Medicine.

In 1972 the National Institute of Occupational Medicine was reorganized as a department of occupational health within the National Board of Occupational Safety and Health. The second list of occupational standards (5) was published in the fall of 1974 by the present decision-making body, the National Board of Occupational Safety and Health, Stockholm. A working group within the Board had been appointed to review the biomedical basis behind the standards. Prior to the final approval the list was sent out for review and criticism to the Confederation of Trade Unions and the Employer's Confederation, as well as to clinics of occupational medicine and the departments of hygiene of various medical schools. The list of occupational standards is formally put into effect by the head of the National Board of Occupational Safety and Health. The number of compounds in the list of occupational health standards is presently around 120. The values are time-weighted averages and/or ceiling values. A ceiling value is defined as a maximum permissible average concentration during a time period of 15 min. Skin penetrating and sensibilizing substances are marked in a special way. In an appendix, carcinogenic substances are listed and divided into three classes. The first class (A) includes substances which are banned from the work environment. The second class (B) includes substances which are allowed in the work environment, but for which the local factory inspectorate should give instructions for handling. The third and last class (C) includes compounds with an established time-weighted average for exposure, although it is stated that the exposure should be decreased to an absolute minimum. The list of 1974 has a higher legal status than the previous 1969 list had.

Other Scandinavian countries

In Norway a translation of the ACGIH list is published by the State Institute of Occupational Hygiene (*Yrkeshygienisk institut*) (67). The values are recommended ones. An official Danish list was pub-

lished for the first time in 1976 by the state authority supervising the work environment (Arbejdstilsynet) (4). This list is mainly a translation of the ACGIH list, but it also includes a small number of occupational standards based on Swedish work. In Finland, the Ministry of Social Affairs and Health published a list of occupational standards in 1972 (56), which had been prepared by a committee within the Ministry. It includes a selection of the lowest occupational standards from the American, Swedish and West German lists.

England

Her Majesty's Factory Inspectorate, under the Department of Employment, issues a nonedited version of the ACGIH list (19). For asbestos (70) and cotton dust (71) a special evaluation has been published by the British Occupational Hygiene Society (BOHS). Both the American values and the two special values proposed by BOHS are published in the *Code of Practice* and in the Inspectorate's *Technical Data Notes*.

Switzerland

The Swiss list of occupational standards is put out by the Federal Accident Insurance Company (Schweizerische Unfallsversicherungsanstalt) (51). The standards are time-weighted averages and ceiling values for 8-h exposure and a 45-h week. The values are taken from the ACGIH list and/or the West German list.

The Swiss list also has a special denotation for skin penetrating and sensibilizing compounds. Carcinogenic substances are treated in a special list and divided into human and experimental carcinogens. Switzerland has occupational standards for ionizing and nonionizing radiation, as well as for noise.

Japan

The Japanese list of occupational standards (25) is established by the Committee for Occupational Standards organized by the Japanese Association of Industrial Health.

These recommended values are based mainly on the ACGIH list. Background data accompanies the small number of compounds that have values that differ from those in the ACGIH list.

Mexico

In Mexico a list of occupational standards is published primarily based upon the ACGIH list (9).

France

France has no officially established occupational standards. In *Cahiers de Notes Documentaires*, the National Institute for Research and Safety (Institut National de Recherche et de Sécurité) gives a rundown of the current American and Soviet occupational standards (73). This institute is a state organ that functions under more than one ministry. In practice the French industries seem to adhere to an occupational standard somewhere in between the two extremes given in the two different lists although they have a certain tendency to prefer American values.

DEFINITIONS AND CRITERIA FOR THE ESTABLISHMENT OF OCCUPATIONAL STANDARDS

The United States

ACGIH defines threshold limit values as airborne concentrations which are believed to protect nearly all workers, day after day, from the adverse effects of the substances in question.

The "nearly all workers" phrase means that there may exist great differences in individual sensitivity and that the small fraction of workers who are the most sensitive may show some effects, such as discomfort at concentrations at or just under the TLV. In addition a few workers may show more serious effects due to aggravation of an earlier existing disease

condition or may, due to sensitivity or aggravation, develop an occupational disease.

The criteria behind the TLVs may be divided into four groups, namely, morphological, functional, biochemical, and other changes. Of these criteria the morphological and functional changes can be said to dominate the background data on which TLVs were based from 1947 to 1968 (57). No statistics from later years have been presented. Around 50 % of all the TLVs established up to 1968 have been based on observations of humans, primarily from industry. Around one-fourth of the TLVs have resulted from animal experiments, most of which have tested for chronic toxicity. The number of animal or other laboratory experiments performed in the study of possible carcinogenic, mutagenic, or teratogenic effects has been surprisingly low. TLVs for a considerable fraction of substances (24 %) have been arrived at by structural analogy, thus without experimental or practical toxicological experience.

More sensitive biochemical methods have been worked out during the last few years and much more knowledge about toxic effects has appeared, especially from laboratory experiments. One may hence assume that the number of criteria based upon animal experimentation has increased since 1968.

The Soviet Union

The Soviet Union's occupational standards are defined as the maximum permissible concentrations of hazardous substances in the air of the work zone that, under daily 8-h exposure, do not cause any disease or abnormalities detectable by modern methods of biomedical examination (54).

During the last two years a new definition for occupational standards as proposed by Sanotskij (49) has been discussed. The new definition would call for an occupational standard corresponding to the concentration of an air contaminant which, by its effect on the human organism directly or indirectly through ecological systems, does not cause any changes in the worker's health status during his work life, old age or in subsequent generations.

Soviet toxicologists employ three fundamental concepts, namely, adaptation, compensation and tolerance. Adaptation is the adjustment of an organism to environmental factors within physiological limits. Adaptation should be permitted according to the new definition by Sanotskij. Compensation is the adjustment of the organism outside normal physiological limits and should not be permitted according to the new point of view (49). Tolerance means that the organism undergoes a weakening brought about by long-term exposure and is regarded as a kind of adaptation. The borderlines between the different concepts are not clear. Recently, Soviet toxicologists have also entered into discussions on the earlier interpretation of the concept of injurious effects. They now seem to consider that not all measurable biological changes are necessarily injurious to the individual.

A common criterion behind the MPCs are changes in the nervous response as seen in experimental animals after exposure to toxic substances (24, 31, 55). Changes in stress reactions, conditioned reflexes, or in the function of the brain cortex have been looked for, in the last mentioned case by electroencephalographic methods (43). Changes in brain functions have also been studied in humans under experimental conditions (for instance, darkness adaptation and optical chronaxy). Psychophysiological methods have been used on man (for instance, the time needed to classify certain words) and on animals (labyrinth experiments). Experimental animals have been examined for biochemical changes (23), especially during recent years. It is very probable that the Soviet values are based to a large extent on animal experimentation, but no statistics on this matter or more details on criteria have been available.

The Soviet occupational standards for chemical substances are worked out on the basis of calculations and standardized experiments formally prescribed by the governmental Permanent Commission for the Establishment of Occupational Standards within the Academy of Medical Sciences. The underlying work is performed in four different steps (48, 50). In the first step, preliminary safe levels are

suggested by theoretical calculations based upon the physical properties of the chemical compound (29), as well as on animal experimentation concerning acute toxicity. The second step includes studies on the subacute effects and the distribution of the substance in the organism, as well as a more detailed experimental estimation of the threshold dose for different acute effects. In the third step accumulation (26) and other chronic effects of the substance are studied with experimental animals. The experimental data are treated according to certain formal calculations, including different toxicological indices (31, 63), and ultimately evolve into occupational standards. These values are adjusted according to a fourth step, which takes place as soon as a substance has been in practical use for some time. Epidemiologic studies are then performed which yield dose-response relationships and serve as a final standard evaluation.

An official rule governs the establishment of occupational standards for carcinogenic substances. It stipulates a safety factor of 100 in the extrapolation of data from animal experimentation (12). At international conferences Soviet scientists have argued that it is possible to establish a zero effect level for at least some carcinogenic substances. As a concrete example, the Soviet Union has established an occupational standard for benzo(a)pyrene (53), but not for β -naphthylamine.

As already mentioned, the new definition of occupational standards proposed by Sanotskij has a clause concerning changes in health status during subsequent generations. It is difficult to know exactly to what Sanotskij is referring, but a likely assumption would be the so-called transplacental carcinogenesis. Soviet scientists are well versed in this special area of chemical carcinogenesis, which means the administration of a potentially carcinogenic compound to experimental animals that are pregnant and the examination of their offspring for tumors during their entire lifetime. The sensitivity of such a test system is highly superior to one involving exposure of adult animals only. Very small doses of carcinogenic substances are able to initiate cellular processes during the development of the embryo that lead to tumor formation later in life (60).

West Germany

In West Germany the maximum allowable concentration in the work environment is defined as that concentration of a gas, vapor or aerosol which, according to present knowledge, does not generally influence the health of a worker exposed on a repeated and long-term basis, usually for 8 h daily and for an average of 45 h/week (52). The values are based on experimental toxicological studies or on experiences with the exposure of workers in industry. In principle observations on humans are regarded as more important than those on animals.

East Germany

The East German definition of an occupational standard is identical to that of West Germany except for the daily exposure time, which in East Germany is 8.75 h (7).

Sweden

The Swedish occupational standard (5) is defined as the concentration of a compound which is sufficiently low to protect workers against injury or discomfort. This protection should be provided throughout the entire worklife and for every worker, as far as can be surveyed. Due to biological variation, very rare effects, as for instance effects due to hypersensitivity, cannot be guaranteed not to emerge. An aggravation of preexisting disease conditions may take place in individual cases. The standards are based upon experimental studies on animals or on humans, as well as on experiences with the exposure of workers in industry.

The Swedish standards are based upon the West German, Czechoslovakian, and American documentations. In many cases, as for irritating and anesthetic compounds, a lower standard has been set than the corresponding American or German one. There is now a conviction in Sweden that irritating, psychophysiological, or long-term neurotoxic effects should not be accepted at all. In some cases, as for some organic solvents, an interadjustment of values for different solvents has also been

made. Moreover, technological feasibility criteria have played a major role in the final decision regarding some compounds, as for instance trichloroethylene.

The listing of chemical carcinogens has been based on experimental and epidemiologic evidence. The main criteria for the grouping into the different classes of A, B or C have been technological; substances which can be avoided without difficulty and are high-risk chemicals have been placed in class A, the rest in class B or C. The values for class C compounds should not be regarded as safe levels of exposure; instead they represent *accepted low-risk levels*.

DOCUMENTATION

A short summary of the basis for all occupational standards established by ACGIH is published, along with a list of relevant references, in a hardbound volume entitled *Documentation of the Threshold Limit Values* (1). The documentation cannot be regarded as satisfactory. In many cases the total relevant scientific information concerning a compound is much greater than that referred to. In other cases unpublished observations are mentioned, as well as outdated observations or reports which are difficult to obtain. The hardbound volume is reprinted at irregular intervals, the last edition dating 1974.

The occupational standards set up by OSHA are based mainly upon the documentation of ACGIH, as well as on the so-called Z-reports by ANSI [e.g., the standard for methylene chloride (3)]. OSHA has voiced the desire to base its standards much more on the criteria work performed by NIOSH as soon as this work becomes sufficiently extensive. The criteria documents by NIOSH [e.g., those concerning ultraviolet radiation (34) and ammonia (35)] are extremely valuable monographs on the toxicology of substances. NIOSH also publishes explanations of the underlying basis for different standards concerning carcinogenic agents, as well as background information on single chemical

substances. Examples of such brief summaries are those on chloroprene, diaminodiphenylmethane, ethylene dibromide and hexamethyl-phosphotriamide. These summaries do not appear on the official list of publications from NIOSH but may be obtained by direct contact with scientists at the Institute.

OSHA also establishes "emergency temporary standards" for single substances. According to the Williams-Steiger Occupational Safety and Health Act such a standard should remain in force not more than 6 months. Before the end of the 6-month period OSHA must present a final decision on the substance in question. The publication of a temporary or permanent standard embraces a rundown of technical, economic, and biomedical aspects, as may be exemplified by vinyl chloride (41).

The documentation behind the Soviet list of standards is not officially obtainable. In some cases an article in a Soviet scientific journal may contain a proposal for a hygienic standard, but it is of course difficult to speculate whether such an article is the only basis for the final occupational standard.

The present list of occupational standards in Czechoslovakia is accompanied by a brief documentation (8), in which physical and chemical properties of the substances, as well as some toxicological limits (for instance, odor limit, limit of narcosis, etc.) are named. Pertinent biomedical data are summarized and references are given.

In West Germany the documentation is published separately from the list (18). This documentation contains a very good summary of the toxicology of the different substances, as well as an argumentation for the standard proposed. A great number of references is given. Only one-third of those compounds found in the list of 1976 are backed by documentation.

The preface to the 1969 list of occupational standards in Sweden (6) stated that the American documentation generally formed the grounds for the evaluation. For a few compounds Swedish scientific experience led to the final decision. The choice of which compounds should be included in the list of 1969 was based mainly upon whether medical data on exposure

were available. Neither a summary nor references were attached. In the list of occupational standards of 1974 (5) the underlying basis for the values was taken for the most part from the ACGIH, NIOSH, West German and Czechoslovakian documentations. The choice of what compounds should be listed was this time guided primarily by the need for action within the Swedish industry. In Sweden there is presently documentation for only a few carcinogenic substances (64, 66).

As mentioned earlier, the Japanese occupational standards have chiefly been taken from the ACGIH list. In some cases special Japanese values are included and background data on them are shortly summarized and referred to in an appendix to the list (25).

INTERNATIONAL WORK

Occupational standards have been the focus of interest both for individual scientists and for international conferences and symposiums (21, 30, 45, 50, 58, 61, 62, 69). It has not been possible to reach a consensus regarding definitions, criteria or methods for establishing the toxic dose and response. From the standpoint of theoretical toxicology, it should be easier to reach a consensus on acute effects, such as irritating and anesthetic effects, than on chronic effects. Indeed, there is in practice a rather good consensus in the standards for substances with irritating properties. As concerns carcinogenic compounds, the International Labor Organization (ILO) issued a convention and a recommendation (22). This organization has also convened a working group for establishing principles for listing carcinogenic substances, as well as for supervising work with them. The International Agency for Research on Cancer in Lyon, an organization belonging to the World Health Organization, sets up ad hoc groups of cancer experts to collect documentation and to perform evaluations on single natural and xenobiotic carcinogenic compounds (20).

DISCUSSION

When maximum permissible concentrations are being established, it is obvious that the values arrived at will depend on (a) the biological criteria chosen and the degree of accuracy of the method used for establishing the criteria, (b) the evaluation of technological feasibility and (c) the general demands made for the quality of the work environment (societal goal). Differences from country to country are probably the greatest for a and b, and they are ultimately reflected in the differences in the official values, some of which can be found in a comparison made by Winell (65). A comparison of numerical values from the Soviet and American lists shows that only around 20 compounds have the same standard in both countries, around 30 compounds differ by a factor of two or less, while around 20 compounds differ by a factor of around 50 (45). In the latter two cases the Soviet values are lower than those in the United States.

The differences in occupational standards, expressed as the quotient of the official American and Soviet standards, for compounds with acute effects, such as irritants and lung-toxic substances (e. g. acetic acid, chlorine, hydrogen fluoride, and ozone), are generally not very great (table 1). Only for acetaldehyde and formaldehyde do quite different evaluations seem to have been made in the United

Table 1. Comparison of American (OHSA) and Soviet occupational health standards for some irritating and lung-toxic gases and vapors.

Substance	Quotient U.S./U.S.S.R.
Acetic acid	5
Acetaldehyde	72
Ammonia	1.8
Butylamine	1.5
Chlorine	3
Chlorine dioxide	3
Formaldehyde	8
Hydrogen chloride	1.4
Hydrogen fluoride	4
Iodine	1
Nitrogen dioxide	1.8
Ozone	2
Phosgen	0.8
Phthalic anhydride	1
Sulfur dioxide	1.3
Sulfuric acid	1

States and the Soviet Union. As regards acetaldehyde, the Soviet Union has also emphasized the odor characteristics (45) of the compound along with its anesthetic effects.

In the Soviet Union, as opposed to the United States, great emphasis is put on neurophysiological parameters in experimental animal studies, as well as on behavioral effects in human beings. It is thus not surprising that the standards for substances with effects on the central and peripheral nervous systems differ systematically between the two countries. The differences are easily seen for organic solvents (table 2). One could argue that Soviet toxicologists have chosen very sensitive methods in order to get low standards. In the preface to the Czechoslovakian documentation an indirect polemic against this principle is put forth (8).

As regards metals and metal salts, the consensus between the American and Soviet values is fairly good (table 3) with some exceptions. For metals affecting the nervous system, i.e., lead, manganese and mercury, the Soviet values are one-tenth to one-twentieth of the American ones. The values for pesticides differ with a factor of 1–25 between the extremes (table 4), a difference which is especially marked for chlorinated hydrocarbons.

Studies on industrially exposed workers seem to be more emphasized in the United States than in the Soviet Union; in the latter country preliminary values for all compounds are established on the basis of studies on experimental animals. American toxicologists focus upon morphological changes in organs (69), while the Soviet toxicologists, by tradition, place greater emphasis upon the functional response of organs, especially those pertaining to nervous system functions. The effects of air contaminants on the behavior of animals and men have received more attention recently (13, 59), not only in the Soviet Union, but also in Czechoslovakia, Switzerland, the United States and Sweden.

A biological effect not relevant to a change in health status is accepted in the United States. Some discomfort, e. g., irritation of the eyes and upper respiratory tract, is permitted in the United States at a certain frequency. Any biological effect which represents a deviation from

Table 2. Comparison of American (OSHA) and Soviet occupational health standards for some organic solvents.

Substance	Quotient U.S./U.S.S.R.
Acetone	12
Benzene	6
Butyl alcohol	30
Carbon disulfide	6
Cyclohexane	13
Dioxane	36
Ethyl acetate	7
Ethyl ether	4
Methyl chloroform	95
Methylene chloride	35
Perchloroethylene	67
Styrene	84
Toluene	15
Trichloroethylene	54
Xylene	8.7

Table 3. Comparison of American (OSHA) and Soviet occupational health standards for some metals and metal salts.

Substance	Quotient U.S./U.S.S.R.
Antimony and compounds	1.6
Arsenic and compounds	1.7
Beryllium	2
Cadmium (metal dust and soluble salts)	2
Cadmium oxide, fumes	1
Chromic acid and chromates	10
Cobalt (metal dust and fumes)	0.5
Copper, dust and mist	1
Copper, fumes	0.1
Lead (inorganic fumes and dust)	20
Manganese and compounds	16.7
Mercury (metal fumes and soluble salts)	10
Nickel carbonyl	14
Nickel, metal	2
Vanadium (dust and fumes)	1
Zinc oxide, fumes	0.8

Table 4. Comparison of American (OSHA) and Soviet occupational health standards for some pesticides.

Substance	Quotient U.S./U.S.S.R.
Aldrin	25
Carbaryl (Sevin)	5
DDT	10
Dieldrin	25
Dichlorvos	5
Heptachlor	50
Lindane	10
Triorthocresylphosphate	1

the normal, as measured with the most optimal method, is not accepted in the Soviet Union regardless of its possible irrelevance to health status. Recently, however, Soviet toxicologists have shown some signs of beginning to accept a certain change, as long as it can be considered an adaptation within physiological limits. This attitude has not yet been reflected in a change of earlier evaluations. According to the new Soviet definition, an occupational standard for industrial chemicals should completely protect the worker and subsequent generations from injurious effects.

Scientific experience, both biological and medical, dominates as the underlying basis for standards in all industrial countries. Quite understandably then experts in work hygiene, occupational medicine, and industrial toxicology are consistently key figures in the establishment of these standards. In some countries which try to perform independent evaluations, such as Sweden, East Germany, Czechoslovakia and the Soviet Union, the occupational health science experts are more or less directly associated with the establishing and supervising authority. In the United States and Finland the experts are associated with a state research body, while in West Germany the experts are engaged by a scientific council that is separate from the authority which supervises the occupational standards.

No official committee seems to have engaged any expert for the evaluation of the socioeconomic aspects of standards. An evaluation of a technologically feasible level of exposure, through the use of the most modern processing equipment and adequate ventilation, was influential to the establishment of a standard for, e. g., trichloroethylene and vinyl chloride in Sweden. However, such aspects are not specifically mentioned in any of the documentation published, though they definitely seem to have played an indirect role in, e. g., the final evaluation of several of the occupational standards published by ACGIH (30). An already established value may also force the development of relevant technology or force a modification of the process (11, 45). One can note the abandonment by industry of one compound in favor of another, as, e. g., when it switches

from compounds listed as carcinogenic to compounds that are not. Also, the Soviet Union seems to allow adjustment of the standards according to what is locally considered technologically and economically feasible. These decisions are administrative; Soviet scientists are insistent upon distinguishing between biomedical and other criteria (45, 50). An overview of the official values, as has been put forth in this article, thus tells very little about the actual work environment conditions in the Soviet Union, as in any other country for that matter.

The evaluation of technological feasibility may also be of another kind, i. e., it may be concerned with sampling, methods of measurement, and the accuracy of analysis. Every method of sampling and of analysis has a certain error and limit of detection. An occupational standard, according to some scientists, should not be established at a level lower than the one possible to analyze with the most sensitive method of analysis; otherwise the supervision of the work environment would not be meaningful. Others do not accept this argument and point out that methods of analysis undergo continuous changes. For instance, exposure levels which were impossible to analyze before the advent of gas chromatography are today regarded as very high from an analytical point of view. This difference of opinion pertains to the establishment of standards in general, but it is especially important for compounds for which "zero exposure" has been demanded or recommended. The concept of "zero exposure" means in practice that estimated values are under the limit of detection for the most sensitive method of analysis. The issues mentioned here are but a fraction of the problems of analysis; even so, they suffice to render it obvious that the authority establishing an occupational standard should also recommend and standardize methods for analysis of each particular compound. This practice is already being followed in the United States by NIOSH with its criteria for a recommended standard and in Sweden in a supplement to the list of standards by Krantz et al. (27).

Comfort criteria may also play an important role in the final evaluation in some

countries. Substances causing an unpleasant odor, e. g., methyl mercaptan (1); irritation, e. g., formaldehyde (1); or an esthetically unpleasant environment, e. g., oil mist (64), have been given stricter standards than would have been the case had their toxic properties alone been considered. There is reason to believe that the increasing consciousness of a sound environment in general ("quality of life") will result in an even greater application of such criteria in industrial countries. A certain interadjustment of standards, as has been made in Sweden for different organic solvents with a similar technical use, in the absence of "hard" biomedical data is a further example of nonmedical criteria playing a role in the final evaluation. This practice means that some standards or norms are more administrative than they are pure biomedical limits between safe and unsafe concentrations. Finally, it should also be emphasized that it is not possible to establish good dose-response relationships for human exposure with epidemiologic methods in the absence of good dose measurements for the relevant periods of exposure. This is a truism, but it is worth repeating in any comparison of the occupational standards of various countries. This fact, added to the great difficulty of establishing dose-response relationships in low-dose areas, especially for effects on certain individuals and long-term effects, makes the establishment of an occupational standard more of an educated guess or an art than an exact science. Ultimately, the greatest problem in improving the work environment may not be so much a matter of the criteria used for the establishment of an occupational standard, but rather the measures taken to reinforce these standards, whatever their level may be.

ACKNOWLEDGMENTS

Prof. Sven Forssman, Copenhagen, is very much acknowledged for his valuable information and criticism during the work with the Swedish version of this report. The authors are much indebted to Pamela Boston for revising this manuscript.

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Received for publication: 1976-12-15