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## MAXIMUM ALLOWABLE CONCENTRATIONS OF ATMOSPHERIC IMPURITIES\*

PHILIP DRINKER<sup>1</sup> AND WARREN A. COOK<sup>2</sup>

ONE OF the most effective proponents of the prevention of industrial disease was Sir Thomas Legge, former Senior Medical Inspector of Factories in Great Britain. He laid down four axioms of which two can well be considered as engineering rules of guidance in our problems of today (1):

"If you can bring an influence to bear external to the workman (i.e. one over which he can exercise no control) you will be successful; if you can not or do not, you will never be wholly successful.

"Practically all industrial lead poisoning is due to the inhalation of dust and fumes; and if you stop their inhalation you will stop the poisoning."

Legge (1) believed that 2 mgs. per diem was about the maximum safe dosage for man and if he breathed 10 cubic meters in a day then his safe concentration in air was 0.2 mgs./cu.m.

In the United States, Dr. Alice Hamilton (2) continually and effectively has pled for clean air as the most important method of preventing industrial disease. J. S. Haldane, a physiologist, had the unique distinction of serving as a president of the Mining Institution of Great Britain, an honor any engineer would welcome. He set the pace for preventing carbon monoxide poisoning by defining the relationship of exposure and activity (3). Later work by Henderson and Haggard (4) at Yale University established very clearly the fact that safe concentrations of such a gas as CO could be defined accurately. K. B. Lehmann (5) in Germany showed the relationship of zinc oxide fume concentration to the febrile response of healthy humans. With a background of Lehmann's original work, Drinker, Thomson and Finn (6) defined exposures to ZnO and human responses in much the same fashion as had been done previously for CO.

Substances such as carbon monoxide and zinc

oxide typify the comparatively few that give what might be called a measurable reaction when breathed by man.

Obviously maximum allowable concentrations (MAC's) for such substances are the easiest to determine. Reactions are acute and well defined. On the other hand, substances like silica, radium or benzol can be breathed for months or even years with the victim entirely unaware of the risk.

Obviously again, such substances involve appreciable difficulties in defining their MAC's and any values require much long-range correlation between exposure and pathological effects. Their interpretation definitely falls into the practice of industrial hygiene and is an art rather than a science.

It would be a serious mistake to consider any of these MAC's as precise. Their correctness varies pretty much with the toxicity of the substance in question—they are reliable for acute exposures to substances such as CO and H<sub>2</sub>S and they are no more than approximations in the case of chronic exposures to slow acting dusts like granite.

## DURATION OF EXPOSURE

In the application of MAC's to the evaluation of an occupational disease exposure and to the control of a health hazard, the duration of exposure must be included. Most of the values presented today contemplate continued subjection to the atmospheric contaminant over the entire work week without injury to health.

If the work week is longer than normal the concentration should be kept at a level lower than the accepted MAC, roughly in inverse proportion to the increase in time. However, if the exposure is for a period shorter than a normal week, great caution should be observed before permitting concentrations to be proportionally greater.

The extent to which the MAC can be exceeded, if at all, for short, repeated exposures depends upon the characteristics of the substance. Where the physiological effect of the contaminant is largely irritative as with such a gas as sulfur dioxide, the tolerable concentration for brief exposure is very little higher than that for pro-

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longed exposure. Although an MAC of 10 parts of sulfur dioxide by volume per million parts of air is considered without effect for an indefinite period, a concentration of only twice this value would cause coughing in a short time.

Even with substances which exert systemic effects on the body, experience has demonstrated that it is dangerous to permit concentrations to rise too high even for comparatively brief periods. Only two hours exposure to a concentration of 300 parts per million ethylene chlorhydrine caused fatal poisoning although it is probable that continued exposure to 5 parts per million would be borne without injury.

Exposure to the silicosis-producing dusts can be greater than the accepted MAC's for short periods without injury to the lungs but greatly excessive concentrations even of such a contaminant are to be avoided as noted by Mavrogordato (7) as early as 1923.

Where the exposure varies, the concentrations can be averaged within limits and again depending upon the characteristics of the contaminant.

One can not average high and low concentrations for severe poisons like CO because a single acute exposure may be disabling or even lethal. But it is not unreasonable to average chronic exposures to substances like quartz or even radium. Thus four hours exposure to dust concentrations of 60 million particles per cubic foot and four hours to 20 might be considered equivalent to eight hours at 40 million particles. That sort of averaging has been used in estimating silicosis risks and now is being used in gauging exposures to radioactive fission products.

#### MAC'S FOR SILICEOUS DUSTS

The concentration of dusts which can be inhaled without injury depends not only on the duration of exposure but also on the free silica content. Within limits the higher the free silica percentage, the lower the MAC.

New York State has developed a very effective series of codes governing work with siliceous rock. Their codes for rock drilling and rock crushing (8) have accomplished a vast amount of good and have set a pattern for preventing silicosis.

New York permits dust counts of 100 million particles per cubic foot for dust from rock containing less than 10 per cent free silica and counts up to 10 million for rock containing more than 10 per cent free silica. The significant item is the

fact that free silica is estimated in the parent rock and not in the air-floated dust. Estimation of silica in the parent rock is routine in mineralogy while such estimates in air-floated dust are difficult and time consuming.

In certain operations such as shaking out castings in the foundry, the air-floated dust may be significantly different in quartz content from that of the parent material. In such a case, it is of course essential to be informed on the quartz content of the atmospheric dust.

#### SENSORY REACTION VS. POISONING

We have heard some acrimonious discussions on whether MAC's should indicate sensory reactions or definite toxic manifestations. For instance, acetone vapors are perceptible at around 200 p.p.m. and somewhat annoying to the uninitiated at about 500 p.p.m. We know of very convincing data that frequent and long exposures to values above 2000 p.p.m. are completely without measurable effect upon man. Such concentrations are substantially below those which cause mild anesthesia but are approaching those of possible inflammability. Carbon tetrachloride, an extremely useful and important solvent, often induces nausea and vomiting in concentrations well below those which cause chronic poisoning. It is submitted that a nauseating atmosphere is hardly a fit place in which to work. Hence a demand is sometimes made that concentrations of carbon tetrachloride vapors be kept substantially below the level set by the usual criteria for selecting MAC's.

#### ZONES OF TOXICITY

In a recent paper Schrenk (9) reviewed the development of procedures used in establishment of maximum allowable concentrations and the criteria on which they are based. A list of MAC's of some 140 common substances together with basic references in support of the values is given by Cook (10). An effort was made in this latter paper to indicate that the values are not precise by listing them only as round figures.

In a series of papers on the response of guinea pigs to various solvent vapor concentrations, Sayers, Yant, Schrenk and others (11) plot on double log paper exposure time versus concentrations. They show several zones, the first which causes death within 24 hours, the second which elicits a serious response, and the third which is

## BOOK REVIEWS

TECHNICAL AND SCIENTIFIC DEVELOPMENTS RELATED TO THE ASBESTOS INDUSTRY IN GERMANY. Board of Trade. German Industry. F.I.A.T. Final Report No. 1070, (March 23), 1947. London: H. M. Stationery Office. 4s. 6d.

This report is a description of the machinery and installation of the German asbestos industry which is considered to be of interest to American industry, and is a supplement to previous reports especially Fiat Final Report 460 and Bios Final Report 404, Item 22. The main problem for the German asbestos industry is regarded at present as one of lack of material, in which the British Zone is not so badly off as the American. The report consists broadly of three sections, one dealing with industrial plant, another with problems of dust control and a third with some experiments made by German scientists during the war to prepare a synthetic asbestos. The present position with regard to the plant and installation is solely an engineering problem. The preparation of a synthetic product has been held up by the collapse of German industry, and not a great deal appears to be known about it, but the basic idea seems to have been "gelling" of sodium silicate with hydrochloric acid, washing out of the gel to remove NaCl by liquefying it under steam pressure, evaporating the solution to 14 per cent  $\text{SiO}_2$  with the addition of 5-10 per cent sugar, introducing a spinning process and finally ageing the fibre, washing the sugar residue and drying. The section on dust control has a direct bearing on general industrial hygiene.

For many years before the war, insurance against the risks of dust and accidents was compulsory. The use of respirators was recommended only in extreme cases, reliance being chiefly placed on an efficient dust control organization. The report gives a translation of the regulation for Dust Prevention in Asbestos Processing Plants issued by the German Government in 1940. This lays down general engineering precautions for dust control, with detailed instructions as to the protection of machines and the provision of exhaust equipment. [Many of these are already in use in Britain, but the details are too technical for abstraction.] An official center for advising on dust prevention, especially in the case of the installation of new plant, was provided by the Government. Children under the age of 18 were not considered suitable for dusty occupations [no details are given, however, as to the regulations for their exclusion]. It was forbidden to eat, or to remain, in dust-endangered rooms during rest periods. Outdoor clothes were not to be kept in workrooms and work clothes had to be cleaned at regular intervals [time not stated].

The writer of the report also interviewed Dr. Luise

Holzappel who had had charge of an organization in Berlin for the investigation of silicosis problems, before the collapse of Germany. She stated that she and her staff had been engaged for some time on the isolation of organic silicon compounds. Two important ones had been discovered, but their chemical composition had not been completely determined when the war ended. One was a silicon compound of the lipid group obtained from the lungs of patients suffering from silicosis accompanied by tuberculosis, the other was a Si-N compound present in normal blood. The isolation of these compounds had been extremely tedious, taking from 2 to 3 years and when the Russians took over that section of Berlin they had ordered the destruction of all material on the ground of risk of infection. Dr. Holzappel considered that there was no risk of tuberculosis provided that silica metabolism in the body was normal, and she regarded disturbed fat metabolism in undernourished workers as a predisposing cause of tuberculosis. She was of the opinion that the compound isolated from healthy blood might have some therapeutic value both in tuberculosis and tuberculosilicotic patients. The striking resemblance between the tissue of a silicotic lung and vulcanized rubber suggested to her the presence of long-chain organic silicon oxygen compounds, probably formed when the fresh surface of quartz grains reacted with some unknown constituent of the blood. The presence of oxygen was necessary, she believed, for that reaction to take place and she further expressed the view that "a compound in which the silicon atoms are completely surrounded by organic radicals probably cannot cause silicosis because such a compound will be insoluble and unreactive". Dr. Holzappel had tried to cultivate the tubercle bacillus on  $\text{SiO}_2$  gel containing various nutrient substances, but without success.

The writer of the report states that further information on the two substances mentioned can be obtained from the Kaiser-Wilhelm Institut für Silikat Forschung in Berlin-Dahlem. The substance formed in normal blood had 1.3 per cent  $\text{SiO}_2$ , 6.5 per cent N, but no iron or cholesterol; it was water-soluble, strongly alkaline, with a melting point over  $250^\circ$  [presumably Centigrade] and had been isolated from the lecithin fraction in the blood. The second was a water-insoluble substance from the lung tissue, and could be concentrated in the ester fractions. The lecithin compound, on the other hand, was almost completely absent from lung tissue. In silicosis the melting point of the extracted mixture of ester-free fat was found to increase in relation to the severity of the disease. Early cases of silicosis yielded a mixture of melting at  $45^\circ$  whilst the material extracted from more advanced cases melted at  $72-81^\circ$ . Extraction of silicotic lungs

gave a higher proportion of lipoids (esters, free fatty acids and phosphatides) than was obtained from healthy lung tissue.—*S. Roodhouse Gloyne, Bull. of Hygiene.*

**THE PRACTICE OF INDUSTRIAL MEDICINE.** By *R. A. Lloyd Davies, M.D., M.R.C.P.*, with a chapter on the hazards of coal mining by *G. F. Keatinge, M.D., D.I.H.*

Reviewed in *Chemistry and Industry*, February 5, 1949.

**THE PRINCIPLES AND PRACTICES OF MODERN COSMETICS. VOLUME II.** Cosmetic materials: their origin, characteristics, uses and dermatological action. By *Ralph G. Harry*, Leonard Hill, Ltd. 17 Stratford Place, London, W.1, 1948, 479 pp.

This book presents in alphabetical arrangement a list of materials commonly used in cosmetics or for cosmetic manufacture. Included are discussions on the origin, characteristics, uses and dermatologic action of cosmetic materials. Thus one may pass from "abracols" to zinc sulfate and find information on formula, molecular weight, occurrence or manufacture, physical and chemical properties, B.P. standard, use in toilet preparations and dermatologic action. The appendices include discussions of methods of U. S. Toilet Goods Association for testing for certain substances and a list of the coal tar colors certified by the Food and Drug Administration. Although the book is written in England, it, unlike many others, has equal usefulness for those who reside outside the United Kingdom. Thus, this volume should be of considerable usefulness to those in the United States who are interested in the preparation or identification of cosmetics and cosmetic ingredients. It is not intended for the practitioner, but it will be found practical for the pharmacist, chemist, teacher and others who have interest in the details of cosmetology.—*J. A. M. A.*

**DETOXICATION MECHANISMS.** By *R. Tecwyn Williams*. John Wiley & Sons, Inc., New York, 1947. 288 pages. Price \$5.50.

This is an excellent review of the literature on the metabolic fate of many organic compounds that are of interest to the industrial toxicologist. This book should be in the library of everyone interested in toxicology.—*Albert O. Seeler.*

**NUCLEAR RADIATION PHYSICS.** By *R. E. Lapp and H. L. Andrews*. Prentice-Hall, Inc., New York, 1948. 487 pages. Price \$6.00.

This book is the outgrowth of an elementary manual on radiological safety. In its present form, however, the majority of the text is on fundamental nuclear physics.

There are 5 chapters of the 18 in the book of specific

interest to industrial hygienists and health physicists. These chapters cover nuclear radiations, ionization chamber instruments, Geiger-Muller counters, radiation measurement technique and health physics.

The book presents the basic principles of the sciences underlying atomic structure and nuclear fission. It is a useful book for reviewing fundamentals for people with technical backgrounds entering the field of nuclear energy production and protection.

The chapter on health physics describes the biological effects of radiation, permissible radiation, radiation standards, safety requirements and monitoring technique.

The appendices also present useful data on isotopes and safety rules now used by the U. S. Atomic Energy Commission. Manufacturers of radiation instruments are presented in the last appendix but this is the type of information which will require frequent revision as will the description of such instruments.

Industrial hygiene personnel will find this book a useful addition to their libraries.—*Leslie Silverman.*

**HISTORY OF FACTORY AND MINE HYGIENE.** By *Ludwig Teleky, M.D.* Columbia University Press, New York, 1948. 342 pages. Price \$4.50.

This historical treatise, while retaining a well-balanced perspective of occupational hygiene throughout the world from the Paleolithic Age to present times, includes much of the strong, stimulating personality of its author. The major developments in the field have occurred since the turn of the century, and throughout the book are evidences of Teleky's active participation over this period, injecting warmth and readability into its pages.

We tend to lose sight of the stern pioneering which preceeded the state of responsive management attitude to industrial hygiene existing today until we read of Teleky's experiences of not so long ago. By 1906, regulations in the large cities of Austria had driven the white phosphorus match industry into the small villages. An example of this industry's hostility to investigation of its occupational disease situation in those days is the treatment accorded Dr. and Mrs. Teleky. After a long day of walking through the hamlets of the Bohemian forest in search of cases of phosphorus poisoning, they reached the village inn owned by the match manufacturer only to be turned away because of the purpose of their presence in the area. Teleky does not leave us with any impression that the need for striving for improved working conditions is past or that we should rest on the gains made to date. He stings any who may feel that everything is as it should be with the reminder that there is no statistical evidence to support any contention that great progress has been made, and he points to the still existent need for "laws and regulations thoroughly worked out and enforced by well trained inspectors."

After a foreword by Dr. Alice Hamilton, itself a



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