TOXICOLOGY

by

WILLIAM D. McNALLY, A.B., M.D.

Assistant Professor of Medicine, Lecturer in Toxicology, Rush Medical College, University of Chicago; Attending Toxicologist, Presbyterian Hospital; Attending Staff, St. Joseph's Hospital, Chicago; Formerly Toxicologist to the Coroner of Cook County, Chicago, Illinois

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FOREWORD

SOCRATES, were he permitted to return to life today, might be amazed to learn that his "juice of the hemlock" was not a poison" but a galaxy of poisons. With endless fecundity the many "hemlocks" of an ancient day have yielded a profusion of toxic entities serving and harming mankind in proportion to the propriety of their application. In some measure it may be maintained that the number of toxic agents surrounding a people constitutes an index of its cultural development. Inescapably intelligent man in his desire to make the best use of materials about him will uncover and produce limitless combinations of elemental substances, some of which will prove to possess dangerous properties. No guilt may be attached to that chemist who, because of a laudable curiosity to learn of what a lump of coal consists, first produced benzene. This plentiful substance, like a myriad of others, is at the same time one of man's helpful servants and one of his treacherous enemies.

While the number of "poisons" knowingly or fortuitously isolated by the technologists of a race may mark its milestones of racial advancement, the "poisonings" of human beings in proportion to their number serve as an index of a people's degradation. Whether by vicious design, accident, carelessness, unconcern, ignorance or superstition, poisonings among a people tangibly represent deficiencies in the plans for human living.

It may be conceived that, in a remote day, those human brains best equipped with information as to poisons were engaged in the preparation of better poisons—agents that acted with dispatch, leaving the fewest tell-tale marks and the least gore. Today, in a world still far removed from human perfection, toxicologists foremostly serve in just the opposite capacity. Theirs is the duty to detect the nature and mechanism of poisonings with such exactness that the guilty may be punished as a deterrent to others who might elect similar activities; to guide therapeutists as to the thresholds demarking safe and beneficent actions of man's natural and synthetic agents from those direful actions associated with use in larger amounts; to plan with industry and commerce for the controlled use of baneful substances and machines, lest the hu-

man elements of industry and commerce be damaged in the performance of their obligations. Thus the toxicologist takes a place alongside the lawmaker, the educator, the healer, the minister, the engineer, as a unit in the orderly organization of mankind—all participating in the conservation of the public well being.

Since the mighty among the toxicologists may not with their own voices and hands directly touch all the agencies requiring their services, they are obligated to record their experience, to appraise and compile the observations of others, and to disseminate their learning to the end that knowledge may not disappear from the earth; that remote man may enjoy the benefits of learning gathered in centers of technical activity; that succeeding generations of technologists may escape the necessity of oft repeated elemental investigations and instead may devote their capacities to needed new endeavors. In this present book one widely experienced and highly skilled toxicologist meets, but does not necessarily finally discharge, his obligations to those about him and to coming generations.

Medicine, in its slow growth toward complete control of its problems, must always progress both as an art and a science. Toxicology is one of those branches of medicine which, more than most others, holds the promise of becoming an almost exact science. In present day America, with its unprecedented complexity of industrial and scientific pursuits, numberless and intricate situations demand a full measure of exactness in toxicologic guidance. In this country there are outstanding toxicologists, many meritorious toxicologic achievements, numerous praiseworthy isolated journal publications, but conversely all too few comprehensive toxicologic books. The advent at this period of this book is no chance happening. Inevitably its arrival hinges on the operation of unvoiced, unseen and unmeasured scientific needs.

It is a refreshing characteristic of this new publication that it treats the outmoded observations of bygone periods only on their historical merits. This book is singularly liberated from the ancient thralldom of the occult in toxicology, and its distinguished author, in breaking with the past save for historical reference, may be marked as the man who replaced many of toxicology's threadbare garments with a raiment suited to a rapidly expanding science.

Time is the master appraiser of all books. Only on the basis of a claimed consortship with future time may any foreword writer seek to act as time's harbinger. Conceded this consortship, let it be said that time will be generous in its increasing recognition of the influence of this book on all the affairs to come to the world of toxicology.

The prime function of any foreword writer is not to praise any author or his writings nor to extoll the merits of any publisher or his printings. Instead, the great duty is to challenge the chance reader who stands hesitant between the title page and the author's introduction. To you who have reached this point, permit the foreword writer to serve you through saying "The world may be made richer if you plunge deeply into the contents of this good book."

CAREY P. MCCORD, M.D.

Detroit, Michigan,
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PREFACE

THIS volume has been compiled so that the medical and legal professions may have a modern toxicological text that contains the results of recent research in the field of toxicology as well as the fundamental facts and basic principles.

The subject matter has been the basis of a course of lectures given students of the Rush Medical College of the University of Chicago, and is considered detailed in description. Sources for the compilation of the subject matter include standard textbooks, reference books, and original literature. Among the textbooks used in this work are: LEGAL MEDICINE AND TOXICOLOGY, Peterson, Haines, and Webster; NOXIOUS GASES, Henderson and Haggard; LEHRBUCK DER INTOXIKATIONEN, Dr. Rudolf Kobert; LEHRBUCK DER CHEMISCHEN TOXIKOLOGY UND ANLEITUNG ZUR AUSMITTELUNG DER GIFTE, J. Gadamer; the UNITED STATES PHARMACOPEIA, Eleventh Decennial Revision; DIE GEWERBLICHEN VERGIFTUNGEN UND IHRE BEKÄMFUNG, E. Brezina; CLINICAL TOXICOLOGY, Erich Leschke; and INDUSTRIAL TOXICOLOGY, Alice Hamilton. Credit is given to all authorities in instances where experiments are noted and definite results have been obtained.

The author has endeavored to produce a text that will be valuable both as a classroom adjunct and as a source for evidence in the courtroom, based upon the analysis of organs from many thousands of human bodies. Considerable space is devoted to carbon monoxide, lead, and arsenic, as these subjects are more frequently encountered in court and in industrial work.

WILLIAM D. MCNALLY, M.D.

Chicago, Illinois.
October 1, 1937.

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SILICOSIS AND ASBESTOSIS

SILICOSIS may be appropriately termed a "depression disease," because in America prior to 1930 little was heard of silicosis, while now hundreds of alleged cases have come to the attention of the medical and legal fraternities. Hippocrates, in his "Epidemics"[1878] was the first to mention the symptoms which we recognize today as signs of silicosis. George Bower[1879] mentioned asthma due to inhalation of dust in the blood and lungs. Lohneiss,[1880] referring to miners, described the effects on them: "The dust and stone fall upon the lungs, the men have lung disease, breathe with difficulty, and at last take consumption." Very little was written on the subject until 1717, when Ramazzini wrote a book on "Diseases of Tradesmen,"[1881] incorporating his views from a personal investigation of mines and industry. The description he has portrayed of silicosis has changed but little up to the present time.

The literature was sporadic in nature. Every thirty or forty years someone would write about disease of the lungs. The first report with microscopic demonstration of silica was made by Peacock.[1882] Greenhow was the first to find the crystalline and small angular bodies, and to identify positively the presence of silicon dioxide by means of hydrofluoric acid.

The first time the term "silicosis" was used appears to have been by Rovida,[1883] in 1871. After 1930 the literature contained numerous references to the etiology, symptomatology, pathology, chemistry of dust, and quantitative determinations of silica in postmortem material. Following the Conference at Johannesburg, South Africa, in August, 1930, the literature was greatly augmented by contributions from every country.

The Committee on Pneumonokoniosis of the Industrial Hygiene Section of the American Public Health Association[1884] defined silicosis as "a disease due to breathing air containing

1878. HIPPOCRATES: 4-Epid., M. 13, Trans. by FARR, 120, 1780.

1879. COLLIS, EDGAR L.: Milroy Lectures: Industrial Pneumonoconiosis, Georgii Agricolae, 1557; translated by HERBERT HOOVER.

1880. LOHNEISS, G. E.: Bericht von Bergwercken, 56, 1690.

1881. RAMAZZINI: De morbus arta ficium diatribe, 1717.

1882. PEACOCK: *Brit. & Foreign M. Rev.*, 11:263, 1860.

1883. ROVIDA: Un caso di silicosis del polmini con analisi chemica, 1871.

1884. *Am. Pub. Health Ass'n. Year Book*, 1932-1933.

silica (SiO_2), characterized anatomically by generalized fibrotic changes and the development of miliary nodulation in both lungs, and clinically by shortness of breath, decreased chest expansion, lessened capacity for work, absence of fever; increased susceptibility to tuberculosis, (some or all of which symptoms may be present), and by characteristic x-ray findings."

In case of death, diagnosis must rest upon two findings: The characteristic fibrotic changes seen in section of the lung on microscopic examination, and by chemical examination showing an excess of silicon dioxide, 1.13 mg. or more per gm. of dried tissue. The normal lungs contain 1.13 mg. of silicon dioxide per gm. of dried tissue.[1885] As silica is a normal constituent of all the food we eat and the water we drink, it is natural that we should find it in all tissues of the body. It is a normal constituent of connective tissue, skin, blood, bone, urine, feces, and saliva of men. The silica in the lung in case of silicosis is derived chiefly by inhalation. Men engaged as grinders, stone cutters, or in occupations where the dust contains silica, are prone to develop silicosis in a concentration of 10 million parts per cubic foot of air, if the dust is 35% silica. The most harmful dusts are those of 3 micra or under. Cement and coal dust favorably modify silicosis.

The author advanced the theory that the fibrosis in the lungs in silicosis is caused by the chemical action of fluorides in the blood upon the silicon dioxide. The presence of fluorides with silica causes silicosis to appear at an earlier date in experimental animals than in animals dusted with pure silica.

To make a diagnosis it is absolutely necessary to have a history of the occupation and exposure of each workman in the silica-containing dust; to have a complete physical examination, and to have x-ray pictures. Detection in the sputum of particles of dust known to be associated with the pneumonokoniosis may assist in diagnosing the occupational sign of the attack. However, knowing the occupation of the man, one would expect to find in his sputum the particular type of dust he had been inhaling. Policard and Magnin[1886] conclude "that the microscopic and chemical examination of the sputum is no aid in the diagnosis of silicosis." They only confirm etiological data much more easily obtained in some other way.

1885. McNally, W. D.: *J.A.M.A.*, 101:584, 1933.
1886. *Presse méd.*, 38:875, 1930.

The inhalation of silica causes an inflammation with the development of fibrous tissue in small, well defined nodules. These nodules are more dense than the lung tissue, and are seen in the x-ray pictures.

Three stages of silicosis are recognized. The most usual symptoms are slight shortness of breath on exertion, non-productive cough, and recurrent colds. There may be less ability to expand the chest than usual, and the elasticity of the chest may be impaired. Usually the normal breath sounds may be somewhat harsh, roughened, and shortened. The cough is usually the first symptoms. At first it is both paroxysmal and non-productive and later is accompanied by scanty expectoration. Later on, the outstanding symptom is dyspnea. The second stage is often manifested by continuation of the shortness of breath on exertion and frequently pains in the chest; as the fibrosis increases and reduces the lung ventilation the symptoms become more marked. A patient may not lose weight, and may appear robust, but shortness of breath, may interfere with his working efficiency. The chest expansion is notably decreased, and chest movements apparently are smaller. In the third stage there is pain in the side, which is probably due to early pleuritis. There is an absence of fever; night sweats are common. The patient, as a rule, is pale; his chest is flattened anteriorly; the expansion of the chest is more limited than in the other two stages; there are local areas of dullness, and the inspiratory breath sounds are shortened, roughened, or more harsh. In the third stage, hemoptysis, loss of strength, and gastro-intestinal symptoms are pronounced. The symptoms increase in severity as the disease progresses. Tuberculosis may intervene at any time. It may be twenty years before the patient is incapacitated. In some instances, however, death has occurred within one and a half years from the time of exposure to silicon dioxide.

Both silicosis and tuberculosis may be present at the same time, and the term "tuberculosilicosis" has been applied to this condition. When there are no cavities, one of the outstanding clinical findings would be a reduced vital capacity, i.e., the volume of air that can be expelled from the lungs after a full inspiration would show a reduction from the normal.

When the individual dies and material is removed at the autopsy, the pathological and chemical examination is the final

ord as to whether or not the case is one of silicosis. The history, the x-ray and clinical findings are subordinate to these findings. In *Industrial Medicine*, February, 1935,[1887] the author suggested that no lump sum settlement should be made in silicosis cases, but that monthly payments be made with the proviso that at the time of death an autopsy be performed and the lungs examined for chemical and microscopical evidence of disease caused by inhaling dust. The following tables, LXIV and LXV, give an analysis of normal lungs and lungs from persons having had various degrees of silicosis. Table LXV is of interest as it gives the occupation of the individual, and reports of investigators from various parts of the world.

TABLE LXIV

ANALYSES OF LUNGS

Case	Age	Ash %	Mg. of SiO_2 per Gram of Dried Tissue	
579	6 Mos. Fetus	1.05	.11	
580	2 Days Old	5.32	.50	
590	3 Yrs. Old	5.21	.21	
606	5 Days Old	3.20	.12	
596	Full Term	5.36	.077	
311[1]	81 Years	6.71	1.86	
312[1]	63 Years	5.61	.92	
441[1]	40 Years	6.17	1.21	
15[2]	51 Years	9.85	.72[3]	
17[1]	43 Years	5.53	1.90	
18[2]	28 Years	3.50	.80	
6[4]	23 Years	4.77	1.10	
16[4]	72 Years	4.40	1.10	
1[5]	Normal		1.40	(Colorimetric)
2[5]	Fetus		.09	

1. McNALLY, W. D.: *J.A.M.A.*, 101:584, 1933.
2. GIESE, WILLY: Beitrage Zur Pathologischen Anatomie und Zur Allgemeinen Pathologie, 1932-33.
3. Hydrochloric Acid insoluble which is nearly all silica.
4. CUMMINS, S. L., SLADDEN, A. F.: *J. Path. & Bact.*, 33:11, 1930.
5. KING, E. J., STANTIAL, H., and DOLAN, M.: *Biochem. J.*, 27: 1004-1005.

The prognosis in silicosis is unfavorable. The silica once lodged in the lung remains there forever, and the lung tissue is never restored to normal. Susceptibility to pneumonia and tuberculosis is increased in all stages of silicosis, especially in the last.

When an autopsy is performed, upon opening the thoracic

1887. "Silicosis—An Old Disease Revived."

cavity there are usually dense adhesions, and it is with difficulty that the thoracic organs can be removed. The adhesions are usually adherent on the lateral, mediastinal and posterior surfaces, with more extensive adhesions from the latter surface. The lungs are not collapsed, but stand out as if a cast had been

TABLE LXV

ANALYSES OF LUNGS, VARIOUS OCCUPATIONS

Case	Author	% SiO_2 in Dried Lung	Remarks
1	Giese[1]	2.24	Stone cutter
3	"	7.98	Miner
5	"	3.50	Foundryman
8	Hackman[2]	2.35	Miner
14	"	3.12	Stone cutter
30	"	5.53	Miner, stone c.
1	McCrea[3]	1.39	African gold m.
4	"	4.47	African gold m.
6	"	2.81	African gold m.
503	McNally[4]	1.40	Mill stone sharp.
300	"	2.60	Granite cutter
446	"	1.09	Zinc miner
1	Pancoast and Pendergrass[5]	1.81	Sand blaster
4	" " "	2.45	Sand blaster
40	Sladden[6]	1.72	Coal miner
41	"	1.78	Potter
42	"	1.80	Coal miner
1	Smith and Wikoff[7]	2.16	Driller
4	" " "	2.69	Driller
6	" " "	1.98	Laborer
3	King, Stantial and Dolan[8]	3.64	
4	" " " "	1.70	
5	" " " "	.81	

1. GIESE, WILLY: Beitrage Zur Pathologischen Anatomie und Zur Allgemeinen Pathologie, 1932-33. (Figures are for Hydrochloric Acid insoluble.)

2. HACKMAN, C.: Beitrage Zur Pathologischen Anatomie und Zur Allmeinen Pathologie, 90, 1932-33.

3. MCCREA, JOHN: The Ash of Silicotic Lungs, South African Inst. for Med. Research, Pub. 3, p. 122, 1933.

4. MCNALLY, W. D.: *J.A.M.A.*, 101:584, 1933.

5. PANCOAST and PENDERGRASS: *Am. J. Roentgenol.*, 26:556, 1931.

6. SLADDEN, A. F.: *Lancet*, 225:123, 1933.

7. SMITH and WIKOFF: *Am. J. Pub. Health*, 23:12, 1252, 1933.

8. KING, STANTIAL and DOLAN: *Biochem. J.*, 27:1004-1005.

made. The lungs are not much increased in size, but show an increase in weight. On section, the lung of a typical case of silicosis will show a dull slate gray, the surface uniformly studded with discrete firm black nodules. The air spaces are emphysematous. The large bronchi are thickened by fibrosis.

The peribronchial lymph glands along the bifurcations of the large bronchi are enlarged and black in color, and, upon section, cut with difficulty and give a gritty feeling. The cut sections are gray, with areas of black scattered throughout. The lung cuts with difficulty and may show irregular spherical masses of dense fibrous tissue scattered over the surface.

The pathology of silicosis is well summarized in the statement on the Medical Aspects of Silicosis made at the International Conference on Silicosis in Johannesburg, South Africa,

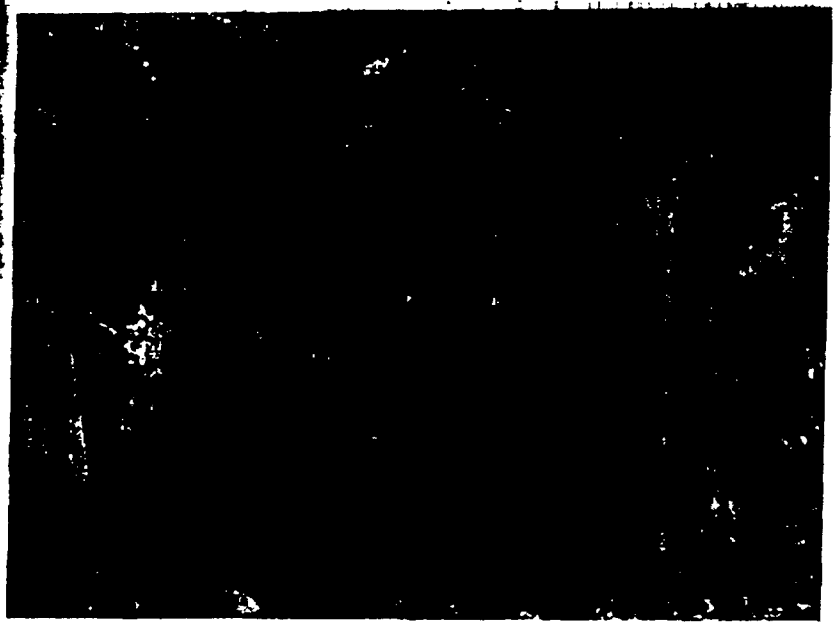

FIG. 28
A Silicotic Nodule

August 13 to 27, 1930. It was agreed that the microscopic pathological changes that may be produced by the prolonged inhalation of silica dust are:

1. The development of a condition designated in South Africa as a dry bronchiolitis characterized by an accumulation of dust-filled phagocytes in or in relation to the terminal bronchioles, with possibly some desquamation of their epithelium.

2. The accumulation of dust-containing phagocytes about and in the intrapulmonary lymphoid tissue and their transportation through the lymphatics into the tracheobronchial lymph

nodes. (The conditions described above under (1) and (2) do not constitute the disease silicosis.)

3. The gradual development of fibrous tissue within such accumulations of phagocytes and the formation of characteristic nodules of hyaline fibrous tissue.

4. Degenerative changes in these foci.

5. The hyaline nodules increase in size by extension at their periphery. Coalescence of adjacent nodules takes place and brings about involvement of further areas of the lungs. (The conditions described under (3), (4) and (5) constitute the disease silicosis.) (See Fig. 28.)

The pleura are nearly always thickened, and contain deposits of dust. The interlobular septa are thickened and contain dust. The primary lesion of silicosis is located in the tracheobronchial lymph nodes, and a chemical analysis of a large number of lymph nodes shows increased amounts of silicon dioxide as the disease advances in the lung. The nodule is characteristic and pathognomonic for silicosis, consisting of a discrete mass of hyaline connective tissue surrounded by layers of fibrous tissue. In some nodules the hyaline material will contain dust, in other sections there will be no dust. (See method of microincineration under Methods of Collecting Dust, page 994.)

The dust count should not exceed 10,000,000 particles per cubic foot when collected by the Greenburg Impinger method, and counted with about 110 diameters magnification. This is equivalent to 300 particles per cubic centimeter (referring to silica dust exposure). This is the standard used in South Africa, Ontario, Wisconsin, and Oklahoma.

In South Africa the degree with which an individual is affected with silicosis has been divided into various stages:[1888] "First, rather more fibrosis than usual; second, more fibrosis than usual; third, ante-primary; fourth, primary; fifth, secondary." In the United States, the stages are called first, second, and third. "The first stage means that definite physical damage to the lungs has been found, and that such damage has resulted from exposure to dust. The second stage means that definite and specific physical signs of silicosis are or have been present, and that capacity for work has been impaired by the disease, though not seriously. The third stage means that specific physi-

1888. RUSSELL, A. E.: *J. Lancet*, 22:605, 1933.

cal signs of silicosis are or have been present, and that capacity for work has been seriously and permanently impaired by the diseases."[1889] (For the complete literature on the various phases of pneumonokoniosis, refer to The Pneumonokoniosis Series by Davis, Salmonsen and Earlywine.)[1890]

Sweany[1891] states that tuberculosis with silicosis renders a roentgenographic examination difficult or impossible in the majority of patients affected with silicosis, because of atypical characteristics or the location of the lesions.

Denny, Robson and Irwin* found in animal experiments that rabbits dusted with quartz, to which less than 1% of metallic aluminum dust had been added, showed practically no fibrosis at the end of treatment.

McCord, Kasper and Fredrick** state that ethyl silicate is used as a vehicle and solvent in paints and lacquers, as a stone preservative, in heat resistant coatings, as a cement bonding agent for refractories and other materials, and as a strengthening or hardening agent in sand molds, brick textile products and the like. Small quantities of ethyl silicate are used in dentistry for sealing of dental surfaces.

Tetraethyl-ortho-silicate, $Si(OC_2H_5)_4$, is a limpid water-white liquid, boiling at 165.5°C. Its density is 0.933 20/20 and its vapor pressure is relatively low. Air saturated with ethyl silicate vapor at room temperatures (25°C.) will contain approximately 17 mg. per liter of the vapor.

Regardless of the method of administration, but with regard to dosage and time element, the administration of ethyl silicate invariably leads to a characteristic response to which most other manifestations apparently are related. This basic injury is at the location of marked hemorrhage into the air sacs, with some rupturing of alveolar tissues. This change may appear well within ten minutes following intraperitoneal in-

1889. Sayers, R. R., et al.: U. S. Bureau of Mines Tech. Paper, 545.

1890. Book I: The Pneumonokonioses (Silicosis)— Bibliography and Laws; Book II: The Pneumonokonioses (Silicosis)—Literature and Laws of 1934; Book III: The Pneumonokonioses (Silicosis)—Literature and Laws, Chicago Medical Press, Chicago.

1891. Sweany, H. C.: Pathologic Interpretations of Roentgenologic Shadows in Pneumonoconiosis, *J.A.M.A.*, 106:1965, 1936.

* *Canad. M. A. J.*, 37, 1937.

** McCord, Carey P., Kasper, Joseph A., and Fredrick, William G.: The Toxicity of Organic Silicon Compounds 1. Tetraethyl-Ortho-Silicate. Manuscript from the Detroit Department of Health, 1937.

troduction of minute quantities of ethyl silicate and without occurrence of the demonstrable local injury within the abdominal cavity. To a limited extent, the capillaries of the heart and heart muscle are likewise injured by ethyl silicate. If death be not immediate, hemolysis may take place leading to hematuria and anomalies in blood counts. Also, in those animals surviving for a few days, an acute nephritis regularly may be demonstrated.

From their animal experiments the authors found that ethyl silicate possesses highly injurious properties.

The minimal lethal dose, when introduced intravenously into rabbits, is approximately 0.2 ml. per kilo of body weight; death usually takes place within one hour. The minimal lethal dose for rats, when administered intraperitoneally, is approximately 0.06 ml. per 100 gm. of body weight; with rare exception, death takes place within four days.

DETERMINATION OF SILICON DIOXIDE

THE whole lung is cut into small pieces and dried. After drying it is ground to sixty-mesh. Some fibrous material may have to be cut with scissors and ground in a mortar. Ten to twenty gm. of this well mixed powder are weighed into a platinum dish and the moisture determined, so as to be able to calculate all the silicon dioxide and other minerals to the dry basis. The sample is then ashed in the electric muffle, using about 5 gm. of the sample at a time, as the material may foam over if a larger sample is used. After the organic matter is all destroyed, a gray to reddish colored ash is obtained. Cool, weigh, and report as ash. If ashed over a flame the destruction of organic matter may be hastened by the addition of ammonium nitrate, or pure hydrogen peroxide. (The loss in weight is due to water of crystallization, carbon dioxide, and the destruction of the organic matter in the tissues.) The ash at this stage may be examined by petrographic or chemical methods, or a combination of the two, but the examination is best made on the original lungs, as ashing causes a change in the appearance of the mineral present. The ash is now digested with dilute hydrochloric acid, evaporated to dryness, and this process repeated three times. The residue is heated on the electric plate with strong hydrochloric acid for one hour. Warm water is added and the residue washed, dried upon an ashless filter

paper, and ignited in a platinum crucible. It is then cooled, and weighed as "hydrochloric acid insoluble." A slight loss of silica may occur at this stage of the analysis, owing to the presence of fluorides, which the author found to be present in all tissues in the body. The ash still contains some iron and aluminum. The residue is treated with cold hydrofluosilicic acid for twenty-four to forty-eight hours, which separates silicates, leaving the free silica. The residue is washed with warm water upon a small ashless filter paper, dried, and ignited in a platinum crucible. The residue is weighed as silicon dioxide. As a further check the residue in the platinum crucible is treated with hydrofluoric acid, warmed slowly under a hood, ignited, cooled in a desiccator, and weighed, the loss in weight being calculated as silicon dioxide.

Lematte and Kohane[1892] have advised the use of perchloric acid and 1% boric acid to prevent the loss of silica due to fluorides. Where it is desired to obtain the total silica, both free and combined, the ash as obtained above is fused with about four parts of a mixture of potassium and sodium carbonates, digested upon the hot plate with warm water, filtered, and evaporated to dryness with an excess of hydrochloric acid. The dry residue is treated three times in the same manner with hydrochloric acid, pulverizing the white residue each time. The final residue is taken up with dilute hydrochloric acid, and washed with warm water upon a small ashless filter paper until tests for chlorides are negative. The paper is dried, ignited, cooled, weighed, and calculated as silicon dioxide, which can be checked by adding hydrofluoric acid as above. The filtrate after treating with hydrochloric acid can be examined for the presence of other minerals. The filtrate in the fusion method cannot be used for the quantitive analysis of sodium or potassium, as these have been added.

For the colorimetric determination of silica[1893] as the silicomolydate, reference should be made to the papers published by King.

A micro-method has been devised where histological sections mounted on a slide can be ignited in the muffle and ex-

1892. Lematte; Kohane: *Compt. rend. Acad. d. sc.*, 196:575, 1933.

1893. King, E. J.: *J. Biol. Chem.*, 80:25, 1928; see also *Chem. Abst., J. Am. Chem. Soc.*, 50:2395, 1928. Schwartz, M. C.: *Indust. & Eng. Chem., Anal. Ed.*, 6: No. 5, 364, 1934.

amined for the presence of silica. Examining these under the polarized light will show the presence of free silica.

METHODS OF COLLECTING DUST

VARIOUS methods have been used in collecting samples. We formerly used the sugar-tube method, supplanting it by the Palmer water spray apparatus. The Bureau of Mines at the Pittsburgh Station[1894] made comparative tests of the

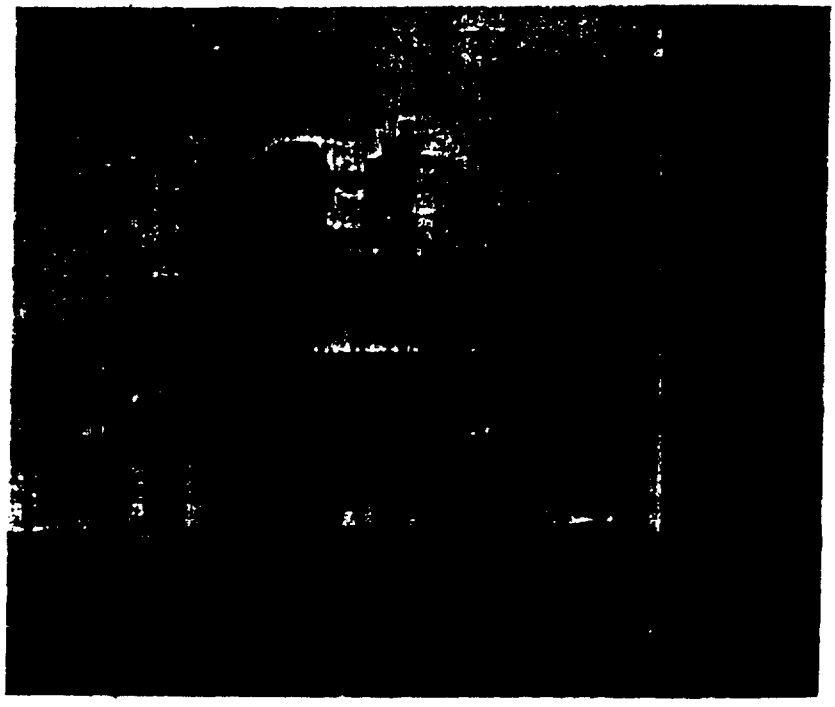

FIG. 29
The Impinger

various methods in use and a new instrument, the Impinger, was evolved (Fig. 29). "In this instrument, the air to be sampled is drawn through a glass tube and impinged at a high velocity into a graduated tube containing water. The dust is momentarily arrested, wetted by the collecting fluid, and in this manner trapped. The apparatus possesses an efficiency of 94% to 97.5% when sampling finely divided silica dust suspension at the rate of one cubic foot per minute." A portion of the

1894. U. S. Pub. Health Reports, 47:654, March 18, 1932.

collecting fluid is removed to a Sedgwick Rafter Counting Cell for microscopic count to determine the number of particles present. An eyepiece micrometer known as a "Whipple Disk" is placed in the eyepiece of the microscope in making the counts. The great objection to this form of apparatus is the weight, as one person cannot carry both parts of the apparatus and tripod. Collecting the dust in this manner gives the chemist an opportunity to weigh the amount of dust collected to determine the amount of organic matter, inorganic matter, how much dust is is in the form of silicates, and how much is free silica or other minerals, all of which can be determined quantitatively. The nature of the organic matter in the air can also be determined chemically and microscopically.

Irwin[1895] states that the micro-incineration method is an aid in the diagnosis of silicosis. Micro-incineration should be regularly included in the microscopic examination of any lung where siliceous fibrosis is suspected, not with any dogmatic predictions in mind but rather as a means towards a more certain diagnosis and a better understanding of the pathogenesis of siliceous fibrosis.[1896]

ASBESTOSIS

ASBESTOSIS is a pneumonokonioses caused by the inhalation of asbestos dust. Although the exact differences between silicosis and asbestosis are not well defined, anatomic and radiologic observations have shown that the appearance of asbestos fibrosis seems to be sufficiently distinctive to avoid confusion, asbestos causing a softer, more delicate, and more diffuse type of fibrotic changes. A full medical and industrial history is emphasized as an aid to differential diagnosis.

Asbestos exists in two chief forms, amphibole, and serpentine. The minerals of amphibole and serpentine are known commercially as asbestos, and are used extensively in the manufacture of incombustible boards, paper, cloth, covering for oil and steam pipes, yarn and rope, and for packing valves.

1895. IRWIN, D. A.: *Canad. M. A. J.*, 31:140, 1934.

1896. Dust References: SARTORIUS, F., and JOTTEN, K. W.: *Zentralbl. f. Gewerbehyg.*, 21:65, 1934; TILLSON, B. F.: *Eng. & Mining J.*, 135:306, 1934; MEITER, E. G.: *Nat. Safety News*, 29:34, 1934; MELLER, H. B.: *J. Franklin Inst.*, 217:709, 1934; MCNALLY, W. D., and SANDER, O. A.: *J. Am. Insurance*, 11:21, 1934; MCNALLY, W. D., and SWEENEY, H., *Nat. Underwriters*, 31:38, 40, 1934.

Most of the asbestos comes from Canada, and is the serpentine N Chrystole. The Canadian asbestos is a hydrated magnesium silicate containing no free silica, but about 44% of combined silica, 43% magnesium, nearly 13% of water, and traces of iron and nickel. The silica is combined chiefly with calcium, magnesium, sodium, iron, aluminum, and potassium. At the present time it is estimated that there are nearly 12,000 individuals employed in the chief asbestos plants in the United States, of whom 10,000 might be exposed to asbestos dust.[1897] Gardner and Cummings,[1898] and Gloyne,[1899] state that the nodular formation found so distinctive of silicosis is not found in asbestosis. While silicosis is predominantly parenchymatous, asbestosis is mainly interstitial. The clinical picture of asbestosis is milder than that of silicosis.[1900] The individual with marked asbestosis will greatly resemble the individual with silicosis. There is the same dyspnea on exertion, the same dry cough, and the more or less indefinite physical signs elicited by the stethoscope. The asbestosis patient is apt to be pasty looking, while the silicotic patient is apt to be very robust in appearance. Lanza states that x-ray appearances are not as clear cut or distinctive as in silicosis and do not lend themselves to ready grouping into progressive stages. "There are less evident pathologic changes in these films and the shadows are finer, more granular and softer than in silicosis. The asbestos film gives the impression of ground glass, and there is no nodulation with the consequent tendency of the nodules to coalesce and give dense opaque somewhat different shadows, occupying the lower third of the lung, except in far advanced cases, when the shadows may occupy the major portion of the lung."

As under silicosis, one must obtain a very careful occupational history. "Associated with exposure to asbestos dust is the occurrence in the sputum and pulmonary tissues of a peculiar formation known as asbestos bodies. These asbestos bodies have been described by a number of observers, and are due apparently to the action of the tissues on the asbestos fiber. It is commonly agreed they are not diagnostic and indicate

1897. Lanza, A. J.: *J.A.M.A.*, 106:368, 1936.

1898. Gardner, L. U., and Cummings, D. E.: *J. Indust. Hyg.*, 13:65, 1931.

1899. Gloyne, S. R.: *Tubercle*, 14:445, 1933.

1900. Lanza, A. J., McConnell, W. J., and Fehnel, J. W.: U. S. Pub. Health Report, 50:1, 1935.

merely that the individual has been exposed to asbestos dust.[1901]

Many of the workers in asbestos have a terminal death of tuberculosis. Such was the case of L. P., aged forty, who died on January 13, 1935, and who had a history of working for fourteen years in an asbestos factory. The postmortem showed that the lung on the right and left sides was bound down by dense adhesions. The left lung contained many small tuberculous cavities. One large cavity was found in the upper lobe. On section the lung showed, in addition to the small cavities, areas of anthracosis, and the peribronchial lymph nodes were moderately enlarged. The tricuspid valves were negative. The aortic valves were slightly calcified. The mitral valve would not admit the small finger, and there were areas of calcification. The myocardium was pale, but firm. Grossly there was no pathology in any of the other organs. Microscopical examination showed a chronic fibrous and caseous tuberculosis of lung and peribronchial lymph node. There were many giant cells, also areas of caseous pneumonia, and fibrous tissue with brownish-black granular pigment, fibrous myocarditis, chronic interstitial changes in the kidney, chronic tuberculosis of the spleen. Anatomic diagnosis showed asbestosis, anthracosis, and silicosis. On chemical examination, the right lung contained 3.72 mg. of silicon dioxide per gm. of dried tissue, and the left lung contained 3.98 mg. per gm. of dried tissue.[1902]

1901. MEREWEATHER, WOOD, W. B., and GLOYNE, S. R.: *Lancet*, 2: 1383, 1934.

1902. Asbestosis References: AMENDOLA, O.: *Morgagni*, 76:16, 1934, *Indust. Bull.*, 13:95, 1934; *Safety Eng.*, 68:74, 1934; BEGER, P. J.: *Deutsche med. Wchnschr.*, 60: 231, 1934; BEGER, P. J.: *Med. Klin.*, 30: 1222, 1258, 1934; ELLMAN, P.: *Brit. J. Radiol.*, 7:281, 1934; MEREWEATHER, E. R. A.: *Tubercle*, 15:69, 1933; 109, 1933; 152, 1934; STEWART, M. J.: *J. Tech. Methods*, 13:70, 1934; WOOD, W. B., and GLOYNE, S. R.: *Lancet*, 2:1383, 1934.

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