Chronic Effects of Mercury on Organisms

by

I. M. TRAKHTENBERG

Translated from the Russian Language and Reproduced in limited quantities by the Geographic Health Studies Program of the JOHN E. FOGARTY INTERNATIONAL CENTER FOR ADVANCED STUDY IN THE HEALTH SCIENCES 1974


FOREWORD TO THE ENGLISH TRANSLATION

This comprehensive work on the Chronic Effects of Mercury on Organisms by Professor I. M. Trakhtenberg, Chair of Industrial Hygiene, Bogomolets State Medical Institute, Kiev, U.S.S.R., was completed in January 1969. It preceded, by only a few months, a period of great public concern in many other countries over mercury in the environment which resulted in intensive efforts to identify sources of environmental pollution, to differentiate the effects and mechanisms of action of various compounds and to develop highly sensitive and accurate methods of quantitation of various forms of mercury in water, soil, air, vegetation, and tissues of fish, domestic animals and man. Thus, Trakhtenberg's work predated the recognition of the unique position among the organo-mercurials which the alkylmercuries, and particularly the methyl compounds, hold. Also, it preceded exquisite methods of mercury detection which, in conjunction with well-
controlled experiments, are necessary to assess the relationship of vague clinical symptoms in man and low levels of mercury exposure.

Nevertheless, this important work brings to the attention of scientists in medicine and industrial hygiene numerous references and summaries of the work of prominent Soviet toxicologists and clinical observers which heretofore have not been widely known to Western environmental and health researchers. It provides a general survey of the physical and chemical properties of mercury and its distribution in the environment. It presents a concise historical account of mercury as an industrial and environmental toxin over the past millenium and the recognition of the need to reduce known exposure to the lowest possible level in mining, in industry, in dental and educational facilities and within urban centers.

The author in his review and in the series of his own clinical observations of industrial workers exposed to low levels of mercury associates symptoms of fatigue, headache, vegetative neurosis, motor weakness, hypotension and cardiorespiratory distress with "micro-mercurialism." He develops the hypothesis that in micromercurialism there is "a series of latent changes, expecially biochemical, neuro- humoral, and immunobiological in nature..." which "do not cause gross somatic disturbances, rather they are reflected in delicate reflex and metabolic shifts." He notes that there is no correlation of these findings and urinary excretion of mercury.

Analysis of the clinical symptomatology in patients supplemented by exposure of laboratory animals to vapors of metallic mercury, ethyl and other compounds of mercury is believed to lead to changes in enzyme systems, immune reactions, and hormone responses. Studies are also described of the effect of mercury exposure on conditioned reflex activity, the hypophyseal-adrenal cortical system and thyroid function.

Although the author recognizes that there are individual variations in response to low levels of mercury, he urges that the air level of mercury in the workers' environment be reduced even below 0.01 mg/ m3 which has been widely considered as an acceptable level. Basic principles of prevention by improved "hygiene, sanitation technology and medical prophylaxis" are presented in a well ordered fashion. Methods of detection of residual mercury in laboratory structures, furniture and equipment are described and means of reducing the use of mercury or its loss to the environment are given in great detail.

The extensive bibliography in this valuable reference covers not only mercury as a toxic agent but studies on its variability and symbiotic relationship with other toxins.

Mercury is indispensable in many aspects of industry, agriculture, medical and dental science today. Professor Trakhtenberg has presented in this monograph some new data, several provocative hypotheses on the mechanism of action of low levels of mercury, and recommendations for remedial measures. These are welcomed for the further evaluations that his report will stimulate and the resulting safer utilization of mercury in the future.

Leonard T. Kurland, M.D., Dr. P. H.
Professor of Epidemiology, Mayo Graduate School of Medicine,
Chairman, Department of Medical Statistics and Epidemiology, Mayo Clinic,
Rochester, Minnesota, U.S.A.
May 22, 1973

SOVIET PUBLISHER'S NOTE

This monograph represents a correlation of many years of research by the author on one of the pressing problems of industrial health and occupational pathology -- the problem of mercurialism. It encompasses various aspects of this problem, contains much factual material on the distribution and circulation of mercury in the human environment, much on contemporary production activity and professions connected with the potential danger of chronic mercury poisoning.
From the point of view of contemporary thought regarding the effects on the human body of factors in an individual environment, it deals with problems of the etiology, pathogenesis and phenomenon of occupational mercurialism, the toxico-dynamics of mercury and hygienic regulation of its vapor content in the air at work sites.

Special attention is given to the analysis of the effects of low concentrations of mercury on humans and other mammals, the interrelation of specific and nonspecific changes and disintegrations during mercurialism. Comprehensive discussion will be made of experimental data on the state of certain metabolic processes, higher nervous activity, thyroid function, and the activity of the adrenal-hypophyseal system.

The theoretical aspect of low intensity toxic effects, i.e.: micromercurialism, is surveyed in this monograph. It will be tied in with the problems of prophylaxis and treatment of poisonings caused by mercury and its compounds. In the proper chapters, a significant place is occupied by an exposition of concrete measures for the prevention of mercurialism - health, sanitation technology, and medical prophylaxis.

There are: 38 tables, 65 figures, and 450 item bibliography (349 domestic and 101 foreign sources).

PREFACE TO ORIGINAL DOCUMENT

At the present time, scientific treatment of the problems of chronic action on the organism of chemical factors produced in the environment occupies a position of greatest significance. It occupies the attention of hygienists, toxicologists, occupational pathologists, practical sanitation workers, physicians in therapeutic and prophylactic occupations, and specialists in industrial hygiene and safety technology.

The hygienic, toxicological and clinical observations of recent years confirm that the effect of harmful chemical substances, encountered under industrial conditions, play a determining role in the development and course not only of occupational, but many common diseases. Successful solution of problems of prevention of the harmful effects of toxic substances is one of the active measures required for reducing occupational and general morbidity.

The development of scientific research in this field requires further experimental analysis of the general mechanism of toxic action, the establishment of quantitative criteria of the harmfulness of active chemical agents, and the establishment of effective measures for averting the prolonged effect of such compounds on the organism.

It is generally known that such widely distributed chemical compounds as those of mercury produce effects in small concentrations.

It must be emphasized that, at the time of mercury poisoning with relatively high concentrations, symptoms are relatively clear. The chronic action symptoms of small concentrations of mercury on the organism bear, as a rule, a more hidden character. This can lead to the conclusion, previously observed, that small concentrations of mercury constitute a danger to the health of workers. Meanwhile, it is known that insignificant quantities of mercury can exert suppressive effects in a majority of persons and can account for the development of chronic mercury poisoning. One can guess that, under modern labor conditions, the majority of the effects on workers of mercury poisoning are caused by small concentrations.

In the course of many operations utilizing metallic mercury or its salts, and also in the use of various types of equipment, the air of the work zone is continually contaminated by mercury vapor. Under such specific work conditions, in which a comparatively small quantity of mercury or equipment with mercury components is used, the compound can become distributed as postulated by N.A. Vigdorchik (1934) whose position is that industrial safety requires hermetic sealing of mercury processes to achieve complete removal of minimal
concentrations of mercury in the air which is extremely hard to do. "It follows," observed the author, "that we must be interested in how such minimal doses of mercury act on the health of workers."

In connection with the development of preventive measures for mercury poisoning, analysis in the light of contemporary theoretical positions based on new experimental evidence and industrial observations characterizing the chronic effects of mercury and its compounds on the body have been worked out in a laboratory of the Department of Industrial Hygiene of the Kiev Medical Institute in the first post-war years (V.A. Lebedev, 1945, 1946) and have endured since. This hygienic and toxicological study of organomercuric compounds has been undertaken by the author of this monograph with L.I. Medvedev (1949, 1959, 1961) and experimental studies with G.I. Kulik (1957, 1959, 1961). Problems concerning the pathogenesis of mercurialism observed by V. Ye. Balashova (1959, 1961, 1962) and N.F. Borisenko (1965, 1966) produced an analysis of the combined effects of organomercury compounds. A.R. Uvarenko (1968, 1969) wrote on the toxicology of new ethyl-and phenyl-mercury compounds. M.N. Korshuna (1967, 1969) observed the effects of industrial conditions on the hygienic evaluation of secondary sources of mercury intake via the air and the effectiveness of mercury removal measures.

The material for the present monograph, varied in character, especially in the methods used, are organically interconnected. It surveys the phenomenon of chronic intoxication with low concentrations of mercury and the pathogenesis arising through degenerative changes and the general relationships of low intensity toxic effects.

In the course of experimental studies it was important to answer another question, namely, the interrelationships of "specific" and non-specific response reactions of an organism to toxicity.

Finally, this task was conceived as forming the basis for higher theoretical criteria for the utilization of physiological, biochemical neurohumoral, immunological and other methods and measures for carrying out experimental analysis of the action of minimal concentrations of mercury in the air, which through prolonged action on the organism does not produce overt symptoms of intoxication, rather, a secret, hidden or latent toxic effect. Essentially, therefore, the features and varied manifestations of chronic mercury poisoning has primary significance in its prophylaxis.

There is an extremely acute need for a monograph which treats of the concrete hygienic measures for the prevention of occupational mercurialism. Physicians encountering it in practicing the prophylaxis of occupational intoxication, should find this book useful.

The organic union of theoretical explanation and practical recommendation, having broad interest not only for specialists, but for general practitioners, is a feature of the present book. This is why this monograph, covering many years of the author's experience in one of the pressing problems of occupational mercurialism, recommends itself to a wide circle of readers -- the practitioners of prophylactic and therapeutic medicine.

INTRODUCTION

"Industrial hygiene, without doubt, constitutes one of the most important activities in the field of hygiene".

(F. F. Erisman. Industrial Hygiene or the Hygiene of Intellectual and Physical Labor. Preface. S.P.6~ 1877.)

Characteristics of the occupations and health of man and conditions of labor and morbidity; who today can deny the presence of an intimate bond between them? Evidently, a variety of factors, with which man is continually in contact in the course of his occupational and productive activities, impairs his state of health. Among these factors, of great significance in modern times is the effect that chemical substances, widely used in various aspects of production, exert in daily life.
In connection with this, this is a time when "Humanity enters into a period of scientific and technical danger, connected with the application of nuclear energy, conquest of the cosmos and with the development of chemistry" (Program of the Communist Party of the Soviet Union, Materials of the 22nd Congress, CPSU, p. 339.) The scientific approach to problems of improving working conditions, in particular, those presenting a potential danger from the harmful effects of chemical substances, occupies the most important place.

Contemporary orientation of research in the field of industrial hygiene and toxicology is significantly characterized by the establishment of new tasks, the importance of which consist of discovering, devising and applying prophylactic measures to further not only the goals of future technical progress, but for the discovery and prevention of harmful effects appearing in the form of specific (occupational) diseases (such as unpleasant effects of low intensity factors) which primarily are considered nonspecific but which can produce harmful changes and disintegration.

The increased interest in the problems described above signify that, under conditions of a socialized industry, especially in light of successful realization of practical measures for purifying the external medium, there exists a special intensity of interest in the possible effects on the human body of these environmental factors. A number of studies have shown that the content of toxic substances in the air of industrial establishments is at a level of concentration which produces observable detrimental changes is now encountered comparatively rarely. In connection with this, comparatively rare forms of chronic occupational poisoning are observed, in this instance, of mercury and its compounds. They can take the form of classical mercurialism, producing quite severe effects, often complete invalidism. The commonly known "Triad"- combination of erethism, tremors and cachexia - as the cardinal symptomatic complex of mercurialism, is almost never encountered today. Such symptoms as polyneuritis, heavy liver damage, and psychic disturbances are not encountered very often while the more moderate phenomena of mercurialism are encountered.

This is the result of a broad complex of effective health measures taken in industries that use mercury. Of greatest significance therefore is the extent to which mercury and its compounds are replaced by other compounds.

It would be unrealistic to assume that the problem of professional mercurialism has already been solved. As with each problem there are special difficulties -- a series of "tight places". First of all, the development of specialized studies and further regulation of sanitary procedures, corresponding preventive measures and hygienic norms for the containment of toxic substances in the air of industrial premises is not all stable nor established for once and for all. It is determined by a series of circumstances: a continued deepening of the general biological concept of the interrelationship of the human body with factors of external environment, and the construction on this basis of a new theoretical concept requiring experimental analysis of newly discovered factors and the observation of them in practice. The introduction of these corrective measures into early evaluation and the establishment of hygienic norms. Especially important in light of the concepts discussed above, is the necessity of taking into account the change in character and action mechanism on the human body of factors in the industrial environment which determine today the importance of studying the effect of hemical substances in low concentrations. In connection with this, interest has been expressed in, and many Soviet researchers take the position of the hygienic significance of low concentrations of hemical contaminants in the external medium (S. V. Anichkov, 1952; R. A. Babayants, 1960; V. A. Pokrovskiy, 1957; V. A. Ryazanov, 1954, 1957; S. N. Cherkinskiy, 1954; G. K. Shakhbazyan, I.M. Trakhtenberg, 1962, 1963, 1967); the pathogenesis and development of general, nonspecific, and specific reactions to toxic compounds (E.A. Drogichina, 1957, 1962; B. A. Kurlyandskiy and co-authors, 1966, 1967; N. V. Lazarev, 1957, 1962; I. G. Fridlyand, 1959, 1966); and the effect of chemical substance on reactivity (S. I. Ashbel' and co-authors, 1948, 1951; V. K. Navroskiy, 1959, 1960 1961; A. I. Pkhomychev, 1960; A.F. Spoyanovskiy, 1957, 1961).
The exposition above relates mostly to problems of mercurialism, which are treated in this monograph.

It is obvious that these are not the only grounds which determined specific interest in the given problem. There is an extremely significant basis for the establishment of an independent order. The most important of these will be explained below.

Mercury and its compounds in various forms are used on a large scale in everyday practice. In the course of time, a contingent of persons encounter mercury, not only workers engaged in metallurgical and metal processing industries, but employees of equipment plants, of the electric industry, and also of the chemical and pharmaceutical industry. Currently mercury is discharged far from the premises of such industries and often, unexpectedly for hygienists, was detected at places where previously it was never encountered. Besides, general knowledge of the sites where contact with workers with mercury is relatively great (mercury mines, factories for the processing of photographic film, industries that produce mercuric chloride, calomel, ethyl- mercuric chloride, ethylmercuric phosphate, and other organic and inorganic mercury compounds), one should point out new areas -- the industrial, community, and educational, where the threat of mercury effects is terribly real today.

The increase in the number of products connected with the potential development of harmful mercury intoxication reflects an important change in the nature of the characteristics and features of objects previously numbered in the category of being "dangerous because of mercury". Thus, at present, from the point of view of the mercurialism hazard, specific impetus is given to the problem in research institutions and laboratories, among them The Bureau of the Registration of Control and Analytical Devices Used for Calibration and Repair, various laboratories in the technical and medical-biological fields, physics and chemistry departments of various higher educational institutions, and so forth are all concerned. This leads to the conclusion that there have arisen new and especially numerous contingents of persons, differing in their composition (age, state of health), experiencing contact with mercury. They differ in their length of exposure to the air which has been contaminated with mercury vapor.

The situation is aggravated when the concentration of mercury vapor in the air of "non-industrial" sites is often found to be rather high in comparison with that of industrial sites. This seems to be a paradox, but is explained by the fact that industrial enterprises, which use mercury, operate under strict sanitary rules, as a consequence of which there are systematic and relatively strict technical, sanitary, hygienic, and organizational measures to prevent the contamination of air with mercury vapor. At the same time, as indicated above, they have taken measures for the prevention of mercury poisoning in laboratories and research institutions, a series of which have fallen under the scrutiny of hygienists.

The maximum allowable concentration of mercury in the air at industrial sites (0.01 mg/ m3), which was established thirty years ago on the basis of literature data and general conclusions about mercury as a toxic substance (general decree of the Narkomtrud SSSR 232, OST 1342-b), has not received any complex revision until the present time. It agrees with the experimental observations on animals in industrial and clinical situations and the analysis of data from special studies. Among these special studies carried out in recent years in the Soviet Union and abroad CM. M. Ginaveye, 1957, 1958, 1960; E. I. Gol'dman, 1956, 1959; V. N. Kurnosov, 1961, 1962; I. L. Kurinnyy, 1963; L. B. Shrayber, Kh. Z. Lyubetskiy and others, 1957; U. Nothduerft, 1959; T. Niculescu, 1956; L. Goldwater, N. Kleinfeld, A. Berger, 1956) and also subsequent observations from practice have permitted the establishment of the possibility of harmful effects of low concentrations of mercury on the organism during prolonged contact with it, often close to the permissible levels. This has called anew the attention of specialists to the observations of A. Stock (1926) of the concept of the possibility of developing, under the influence of insignificant concentrations of mercury, a symptomatic complex, known by the name of "Micromercurialism". One must remember that in speaking of micromercurialism as a "self-contained symptomatic complex produced by chronic inhalation of mercury vapor in
especially low concentrations" (Ours I.T.), N. V. Lazarev (1938) stated that the appearance of mercury in the indicated concentrations "appears to be a harmful minor component of the air of places where it is used constantly, although it is not recorded as yielding real poisoning".

In the course of our research we found that our opinion on the importance of the effect of mercury in low concentrations depends, first of all, on a series of conclusions from results of observed changes and damage produced by it.

An attempt at similar generalization was undertaken based on analysis of changes caused by mercury in different systems of the organism, both in experimental conditions, and in human studies. The union of experimental study of these changes with a hygienic evaluation of production conditions is basic to the development of effective measures for the prophylaxis of mercury poisoning.

In order to systematize the materials obtained by us, concerning primarily the effect on the body of low concentrations of mercury, it was necessary first of all to decide how best to approach one of the principal problems: namely, whether it is better to search material published in current literature, relating to various aspects of the problem of mercury poisoning, or more expediently, to confine oneself to those which deal with the effects of small quantities of mercury only. It is considered that, our materials and data about which questions arise, reflect two sides of one problem. We consider proper those questions dealing with the chronic action of mercury, which emerge from all previous work. In connection with this, in the light of previous studies and results, there was the previous account of problems of the physical and chemical properties of mercury, its distribution in the external environment, particularly in the atmosphere, soil, and in food products. Data on the content of mercury in the human body and its determining biological role is explained at length. We will deal with the basic problems of the toxicodynamics of mercury and its compounds. In subsequent chapters we will attempt to analyze our data on the content of mercury in the air around various types of objects and sites where mercury and its compounds are used, and also results of observations concerning the effect of small concentrations of mercury in the bodies of workers.

In the monograph we shall deal at length also with materials based on experimental studies. Previous data were accumulated in chronic experiments (where exposure to the daily effects of concentrations of mercury on the order of 0.006-0.05 mg/ m3) on warm-blooded animals revealed proteinemic shifts, changes in conditioned reflex activity, disturbances in the hypophyseal-adrenal cortex, changes in the functional activity of the thyroid gland, changes in the cardiovascular system, indicators of immunobiological reactivity, and morphological changes in the blood and organs.

A separate section deals with an analysis of current data on the prevention of mercury poisoning. In this chapter are discussed hygienic recommendations for the structure, equipping and containment of sites in which mercury is used, the techniques of working with mercury and individual hygiene measures. Simultaneously are set forth, the problems of control of mercury content in the air of such buildings, methods and content of demercurializing measures, problems of organizing periodic medical checkups of persons working with mercury.

The realization in practice of these recommendations will facilitate effective prophylaxis of chronic mercury poisoning and the establishment of hygienic conditions for working with mercury and its compounds.

In conclusion, please note that the details of establishing such practices will be dealt with in the various chapters, and we hope this first book will put before the reader a clear exposition of the processes under consideration. We also hope it will clarify the principal position with which contemporary hygienic aspects of the problem of occupational intoxication in particular, of chronic mercury intoxication, are evaluated.
Such premises, were the basis for writing this book, especially dictating its content with regard to a certain prophylactic orientation.

It is considered that during the process of sequential accounting of problems intimately connected with the problem of mercurialism, the author cannot avoid dealing with a series of more general positions having principal significance. The question is, in particular, of the aboved-mentioned regularities of manifestations of low intensity toxic effects, interacting generally and specifically in the reactions of the organism, to the effect of chemical factors of the environment, providing criteria for experimental foundations for hygienic norms.

An instance of departure from the principal subject contained in the book, can be justified by the position that it constitutes a topic of universal interest. Especially one can draw the interest of hygienists, toxicologists, occupational pathologists, and any persons expressing an interest might be especially gratified by having such subjects brought to their attention.

MERCURY IN THE HABITATIONAL ENVIRONMENT OF MAN AS AN OBJECT OF HYGIENIC AND TOXICOLOGICAL RESEARCH

"Recently I observed a young gilder; having been ill two months, he died. Having paid no attention to the discharging mercury vapors, he began to fall into a state of cachexia. Later he had a deathly pallor, protruding eyes, heavy breathing, [was in] a dazed condition."
(Bernadino Ramazzini. 1700 "On Diseases of Artisans". Gosmedizdat SSSR, M., 1961, 32)

"...but money, which they received as profit, did not become poisonous because the factory was filled with mercury vapor."
(A. Levitskiy. "From the Field of Collision Between General Hygiene and Capital". Journal of the Society of Russian Physicians in memory of N. I. Pirogov, 1908, 2, 155)

Metallic mercury has been known since ancient times, earlier than lead, copper, iron and other metals. It was widely known for its property of having a bright color of cinnabar and the ease with which it is obtained from ore.

Regarding the development of the mercury industry, its basic history involved three primary locations, Almaden and Idria in Europe, and Peru. The first two sites have been worked right up to the present. In the middle of the eighteenth century mercury was discovered in California and Italy, and at the end of the nineteenth century in Mexico and Russia.

The best known compound of mercury is corrosive sublimate or mercuric chloride. The method of obtaining it by sublimation was worked out by J. Kunkel in 1716. In 1799, E. Hobard discovered a second compound of mercury, mercury fulminate.

The production of mercury and its compounds grew little and followed generally the development of physics, chemistry and electro-technology. This elucidated other specific properties of mercury compounds, which, when utilized alone or in combinations with other things, are widely used today in everyday life.

Along with many discoveries which made mercury widely utilized was revealed one glaring deficiency, the possibility of toxic action on the body. Quite a lot about this property of mercury is known and has been for a long time. Arab alchemists and surgeons primarily knew that it was a poison for scorpions and other pests that infest houses.

Especially indicative are the illustrations in the great work of C.Agricola "On Mining and Metallurgy" (1556) in twelve volumes, which point out methods used by workers of that time for isolating molten mercury from cinnabar.

A new development in the handling of mercury occurred in the classical work of Bernadino Ramazzini (1700) "On the Diseases of Artisans", which clearly explains the working conditions prevailing in that period in the crafts and
manufacturies. He describes workers engaged in the manufacture of mirrors and says that as a consequence of handling mercury these people manifested paralysis, asthma and other afflictions.

In speaking of diseases of miners, Ramazzini especially noticed that "...the most lethal danger for shaft workers were vapors emanating from the ores which contained mercury". On this he cites the data of the renowned anatomist, C. Fallopio (1564) which confirmed that, workers in mercury mines "...could not endure the work conditions for three years". Under the influence of mercury vapor workers quickly developed tremors, then signs of paralysis, and cachexia. It is noted, in connection with diseases of mercury among workers in mercury mines, the quotation from a book of Lucretius: "Who has not seen or heard, how in so short a time they are killed, and that the strength of all life is taken, those who must achieve their living by such work?" Hygienic research on industrial mercury poisoning has its history. In it much has been discussed, not only from the point of view of development of the concept of professional or occupational mercurialism, but from the position of reducing social opposition between society in general and hygiene, with its broad applications in the field of protecting the national health. Experimental observations on the distribution, development and consequences of massive mercury poisoning among the workers of the Podolsk district in pre-revolutionary Russia was described in a basic article by V. A. Levitskiy "In the Field of Collision Between General Hygiene and Capital" (1908). In it the author noted, according to the capitalist system, the extent of the responsibility assumed in preserving the health of the workers.

As a result of sanitary research into the working conditions of craftsmen engaged in hat making and using mercuric nitrate for the treatment of felt, V. A. Levitskiy (1901, 1908) along with a participating surgeon, S. N. Mikhaylov, described massive mercury poisoning, which in 71% of those studied, took a severe course towards disintegration of the nervous system. In his report on the results of these studies, V. A. Levitskiy wrote: "a large group of the population are exposed to slow acting, but surely poisonous, effects leading to gradual death and physical dysfunction. It is impossible to look at such a picture peacefully: it leads rapidly to energetic intervention. One must state that the opposition of V. A. Levitskiy and his followers against the transition of healthy workers into invalidism was by a method of treating floss with potassium hydroxide. In such circumstances opposition could not be successful. So long and so futile were the past struggles of the French workers' organization for the adoption into industry of mercuryless methods for making felt, that V. A. Levitskiy went especially to Paris to acquaint them with his method.

Mercury poisoning in the past carried with it, as a rule, a massive character. To illustrate this view, one can refer to the data of A. Kussmaul (1861), and to a series of statistical materials pointing out the significant distribution of mercury poisoning in England, Germany, Spain, and other countries at the end of the last century (L. Teleky, 1912; F. Koelsch, 1937; T. Neal, 1938; A. Hamilton, 1925; E. Holstein, 1937; and others). One can take the following descriptions and other indicators of the conditions of massive mercury poisoning as examples. A mine explosion in Idria (Austria), where mercury vapor was distributed through most of the area produced poisoning in miners and members of their families; and an accident aboard the English vessel "Triumph", where there was spillage of a significant quantity of mercury, which led to the intoxication of two hundred persons.

It is relevant to note that even today in many capitalist countries there are cases of heavy mercury poisoning. For example, in the beginning of 1966 there appeared an article on serious mercury poisoning in one of the mines in the province of Keniya in Turkey. Mercury vapor poisoning killed 15 miners and 205 were admitted into the hospital. It is not accidental that among those demands, which workers in the mercury mines put before industrialists, one of the most basic was the need for improving working conditions. It is sufficient to reflect upon those violent events at the mercury mines of Monte Amiata in Tuscany (Italy) in November 1968, when 48 miners remained more than two weeks in a
mercury shaft at a depth of 170 meters before the owner of the mine capitulated to their demands.

Serious mercury poisoning in the past has arisen as a consequence of the action of mercury compounds. It is known that at the end of the 19th century, mercuric chloride was widely used, especially in medical practice. A. G. Bodosko (1901) in his dissertation stated that, in 1889 and 1890 four times the number of poisonings with mercuric chloride were recorded than from 1880 to 1889. H. F. Mirochnik (1934), referred to literature data recording the significant increase of poisonings with this compound in the period 1900 to 1910. Naturally, in this and preceding years, there appeared many independent clinical and especially experimental studies carried out on the subject of mercuric chloride poisoning. (N. Bernatskiy, 1869; A. Dubelir, 1875; I. Kaspar'yants, 1872; B. S. Koshnitskiy, 1898; and others).

In the second half of the last century, in connection with the appearance of the first works in the field of the chemistry of organo-mercurical compounds, the observations of several scientists were used in experimental studies on the toxicology of organomercurical compounds (V. Prumers, 1870; K. Balogh, 1875; R. Herr, 1887). The increase in quantity of industrial processes linked with the use of mercury at the end of the last and the beginning of this century, determined over the course of years, a high interest by hygienists and toxicologists in the problem of mercury poisoning. This activated the interest of sanitation physicians in the problem of prophylaxis of occupational mercurialism, making possible the introduction into industry of a series of health measures. Later this led to some reduction in the number of mercury poisoning cases among factory workers and pointed out the character of the phenomenon of such poisonings, which were not, in all cases, as severe as before: poisoning progressed slowly, and symptoms of poisoning often appeared after cessation of contact with mercury. Such measures at that period gave evidence of relative safety, which led to the conclusion that, at the beginning of the twenties there were observed tendencies towards diminution in research in the field of occupational mercurialism. However, in actuality "safety" was more than doubtful. Research done at the Institute Imeni V. A. Obukha, published in 1925, described cases of mercury poisoning among workers of the felt industry and employees of shops using various mercury-containing instruments and apparatus, again called to the attention of hygienists the problem of occupational mercurialism.

A new milestone in research on occupational mercury poisoning later appeared in 1926 in a work of the German chemists A. Stock (1926) on the possible toxic effect on the human body of very low concentrations of mercury (thousandths of mg/m³).

The view of Stock and his colleagues who published after him the correct diagnosis of unusual disintegrations in the state of health of those working with mercury, which at first physicians had not connected with the effects of mercury. As is now known, they classified this state as a phenomenon of the prolonged action on the body of small concentrations of mercury and gave it the name micromercurialism. The latter, according to A. Stock, was often encountered in persons working with mercury. They had not been diagnosed by physicians as suffering from a condition of "mercury" etiology however. A. Stock assumed that the development of mercury poisoning is diagnosed less often than had previously been thought. Thus, he postulated, as did Pascal and Faraday, who used mercury in their laboratories, that exposure through time led to heavy mercury intoxication. It is known that Faraday used mercury as a cathode in electrolysis. He developed psychic disturbances, acute asthenia and loss of memory. Despite treatment in a psychiatric hospital, he was practically incapable of developing and participating in scientific activity.

The work of A. Stock (1926) on the possibility of unpleasant effects of low concentrations and doses of mercury led to heated discussion in the pages of medical journals. There appeared a series of articles, which expressly treated the problem of the effect on humans and other mammals of small concentrations of mercury (G. A. Malov, 1927; M. P. Minker, 1927; L. I. Berger, 1928; R. N. Vol'fovskaya, 1928; and others). In these and following years up to the present,
in the Soviet Union and abroad, there have been published a significant number of studies of a hygienic, clinical and toxicological character with regard to mercury and its inorganic and organic compounds. Among these, several studies were published by the Institute Imeni V. A. Obukha, the Leningrad Institute for the Study of Occupational Diseases, the Kharkov Institute of Industrial Hygiene and Occupational Pathology.

Problems of occupational mercurialism and its prophylaxis in the post-war years was the object of research in a series of hygienic laboratories and clinics of occupational pathology: (Gorkiy Institute of Industrial Hygiene and Occupational Pathology, the Occupational Pathology Clinic of the Institute of Industrial Hygiene and Occupational Pathology of the Academy of Medical Sciences of the Soviet Union, the Chair of Industrial Hygiene of the Kazan Medical Institute and others.) There was especially broad development of these studies in the toxicological and hygienic laboratories of Kiev.

The improvement in working conditions, the continued perfection of preventive measures in the field of industrial hygiene, the systematic effects of sanitary controls in the fulfillment in factories of hygienic norms and regulations all determined a sharp drop in the level of occupational poisoning and altered the characteristics of the phenomenon. If, in previous years, acute forms of poisoning predominated, at the present time the percent of these has decreased more than twofold.

Simultaneously, we must turn our attention to the fact that, among toxic substances producing chronic forms of occupational poisoning, the most interest is directed today, along with benzene, ethyl gasoline and lead, to mercury and its compounds. In a significant percent of cases these chronic poisonings, according to data of Ye. N. Marchenko (1959), progresses without loss of work ability. Thus, of the chronic mercury poisonings registered in the RSFSR in the past year, about 75% of the cases progressed without loss of working capacity.

Analysis of the features distinguishing the structure and character of the phenomenon of industrial intoxication in the Ukrainian SSR has been made. Thus, as in the RSFSR, the number of cases in the Ukraine of acute and chronic poisoning has diminished from year to year. On the background of this lowering, one must pay attention to the unique character of the dynamics of occupational mercurialism. The number of chronic mercury poisonings occurring in 1953-1954 numbered 45.5% of the total number of chronic industrial poisonings. These decreased sharply later. In 1955-1959 the total number of these was 13.2% of all poisonings. However, in recent years they have grown (to 20.6%). This is caused by a number of contingencies arising from the employment of mercury under industrial conditions, and also because of improvement in the diagnosis of industrial poisonings in general and occupational mercurialism in particular.

The basic trend in industrial mercury poisoning research in the last ten years is the analysis of the action mechanism of small concentrations of mercury on the body and hygienic research into working conditions for new types of work and industrial operations connected with the possible generation of vapors of mercury and its compounds.

Among the studies of a toxicological, clinical and hygienic character, which treat the question of potential danger of the effects of small concentrations of mercury are, first of all; the works of M. M. Gimadeyeva (1958), E. I. Gol'dman (1958), E. A. Drogichina, L. C. Okhnyanskaya (1954, 1962), B. N. Kurnosov (1962), I. L. Kurinnyy (1959, 1961), M. N. Sadchikova (1955), L. B. Shrayber, Kh. Z. Lyubetskiy (1959), and others. Results of these and other work, completed in the following years (V. G. Beletskiy, 1965; N. I. Petrov, 1966; V. N. Federman, 1965; and others), and based on their concrete recommendations, the successful realization of the latter in conditions of daily use have made possible at the present time a lowering of the content of mercury in the air of work areas, and the prophylaxis of its effect on the body of workers.
CHAPTER ONE

GENERAL SURVEY OF MERCURY AND ITS DISTRIBUTION IN THE ENVIRONMENT

Physical and Chemical Properties of Mercury and its Compounds

Why does the wide use of mercury and its many inorganic and organic derivatives in various branches of industry, agriculture, science and technology, medicine and biology occur? What properties of mercury determine its significant distribution in everyday use?

Metallic mercury, appearing at room temperature conditions as a liquid metal, has the highest (for liquids) specific gravity and the highest (for metals) melting and vaporizing temperature, relatively high electro- and heat conductivity, significant chemical stability and density. Thanks to these properties it is used in the production of thermometers, barometers, areometers, electric contacts and a multiple of other physical and chemical devices.

The arc spectrum of mercury is especially rich in ultraviolet rays. Therefore it is used in the production of quartz and fluorescent bulbs, and also for luminescent lighting.

Mercury has the property of entering into combinations with most metals, forming amalgams. This property of mercury use to be widely used for the extraction of useful metals from ores and alloys, with silver and gold in various uses, and for coating mirrors. This property of mercury generated its use for the amalgamation of silver and gold for the preparation of dental fillings.

The catalytic properties of mercury are significant in their use in the production of acetaldehyde from acetylene, and also in the analysis of organic substances for the determination of nitrogen.

The specific gravity of mercury is: at 0°C -- 13.59546, at 20°C--13.54616, at 100°C--13.35166.

Under ordinary conditions mercury appears as a bright silvery white heavy metal. It freezes at a temperature of -38.89°C. Its boiling point is 357.25°C. However, at ordinary atmospheric and industrial environmental temperature conditions it has a noticable partial vapor pressure (at 0°C--0.00019mm Hg standard, at 20°C--0.0012 mm Hg. standard, etc.). The above described properties of mercury distinguish it from all other metals.

Upon vaporizing its behavior in the air under standard temperatures is that of a colorless vapor having no odor. Its presence in the air is detected only by chemical analysis. Thus in cases where an organoleptic amount of mercury in the air has not been discovered, there is often created among mercury workers the illusion that it is absent from the air and harmless to the environment. Besides this, mercury is easily disseminated in the air of buildings and afterwards is found not only near its place of constant use, but quite far removed from it. Mercury vapor penetrates the pores of the body comparatively easily, and this property of mercury vapor called itself to the attention of hygienists as often "....there appear to be cases of poisoning through the walls" (B. B. Koyranskiy, 1923).

The considerable hygienic significance of data on the vaporization rate of mercury and pressure of its vapors should be noted. These observations therefore should be used first of all in the determination of zones of the greatest accumulation of mercury vapors in the air of industrial sites and shops by calculation and the establishment of necessary volumes of pure air. The vaporization rate of mercury, as with other high boiling point volatile compounds, is connected with its vapor pressure, which when saturated at a given temperature, an increase in the temperature can significantly increase the vapor pressure. Change in the vapor pressure is dependent on temperature as expressed in a logarythmic equation. The degree of this increase in case of a further increase in temperature diminishes. An analysis of the change in pressure of a saturated vapor in relation to temperature for chemically pure substances and certain mixtures was described by V. G. Matsak and L. K. Khotshmanov (1959), who
indicate that, "the farther the temperature of the substance departs from the boiling point (diminishing), then the faster the vapor pressure falls". One can postulate quite an important hygienic significance from the point of view of the possibilities of contamination by mercury of the air of industrial buildings which supports an earlier established (in connection with required norms) mandatory temperature regime. Thus, at an increase in temperature between 20--30°C one can expect an increase in the vapor pressure and consequently an increased concentration of mercury in the air by 2.32 times (Table One).

It is necessary to point out that there is a marked dependence of the degree of vaporization of mercury on various temperature conditions. Hygienists as a rule, find themselves divided as to data on the amount of partial pressure of mercury vapors, saturating the air at various temperatures. In these cases, when we speak simultaneously of the concentration of mercury vapor as dependent on temperature, we cite

**TABLE 1**

Pressure of saturated mercury vapor and the coefficient of increase in vapor tension at temperature increases of 10°C, (according to V.G. Matsak and L. K. Khotsyanov, 1959).

<table>
<thead>
<tr>
<th>Temperature range in degrees C (T1--T2)</th>
<th>Vapor pressure at T1 mm Hg</th>
<th>Vapor pressure at T2 mm Hg</th>
<th>Coefficient of increase saturated vapor pressure at ten degrees temp.</th>
<th>Maximum conc. at T1 and T2 mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>0.000185</td>
<td>0.000490</td>
<td>2.65</td>
<td>2.02</td>
</tr>
<tr>
<td>20-30</td>
<td>0.001201</td>
<td>0.00278</td>
<td>2.32</td>
<td>13.1</td>
</tr>
<tr>
<td>40-50</td>
<td>0.306079</td>
<td>0.01267</td>
<td>2.08</td>
<td>-</td>
</tr>
</tbody>
</table>

(commonally as an example) the specific amounts of these concentrations. Nevertheless, for the solution of series of actual hygienic problems most often connected with the calculation of necessary air circulation at industrial sites where mercury is used, it is necessary to put down detailed information regarding the amount of mercury vapor concentration filling the air at different temperatures. Recently there have appeared recommendations setting forth these quantities derived from characteristic equations (as an analogy, an analysis would delineate the thermodynamics of moist air), derived from partial pressure amounts (V. N. El’perman, 1961). From this, attention is called to the fact that at temperatures of 30-40°C at the surface of mercury a concentration of its vapors exceed the maximum permissible quantity for industrial sites 3,000-6,000 times, and at temperatures of 60-80°C the temperature of tool surfaces in shops using mercury, by thirty thousand-eighty thousand times. It is obvious that so high a concentration of mercury vapors in the immediate neighborhood of work areas constitutes a significant mercury content in the respiration zone of workers. At low air temperatures (from -30°C to -10°C) the quantity of mercury vapor saturated the air, approaches the permissible limits which have commonly been observed at industrial sites where mercury is used. In connection with this, it becomes clear why in these enterprises, on surface structures in winter time, especially on surfaces of skylight outlets through which air leaves a workshop, mercury vapor often condenses. From these facts it follows that it is a very important conclusion for hygienists that, if towards the beginning of the warm period of the year mercury condensate is not removed, it will remain a self-contained source for the introduction of mercury into the air of industrial premises. Besides that, one can point out that based on preceding data, one of the effective methods for scrubbing mercury vapor from the air (its removal into the atmosphere), is cooling by means of contact with a cold surface or by atomizing it with a cool fluid or powder. Thus, from the preceding materials it follows that the concentration of mercury vapor in the air increases proportionally to increases in the surrounding temperature. From this is derived an important conclusion for the hygienist on the possibility of the introduction into the respiratory zone of workers of a significant quantity of mercury vapors in such conditions, when in the carrying out of industrial processes is
accompanied by an increase in the air temperature or when this increase is connected with a change in the outside temperature. Evidently the hazard of mercury poisoning under industrial conditions where it is simultaneously possible for the action of high temperatures in the surrounding air becomes almost certain. It must be remembered that high temperature of the air medium under conditions of "mercury" production not only determines more intensive release of mercury into the respiratory zone of workers, making possible an increase in the intake of mercury into the body, but at the same time indicates the hazard of a possible increased toxic effect on workers, in the course of their labor. A condition of hyperthermia, arising in the body and accompanied by a series of functional changes, combines with the development, under the effects of mercury, of a toxic effect, which can aggravate the effects of mercury symptoms caused by this action. Through treatment of the following materials it will be shown that, in such combined simultaneous effect on the organism of toxic and temperature factors one can infer a circle in which disintegration and change, caused by mercury and high temperatures, reinforce each other causing the organism to become more susceptible to the action of each of these indicated factors.

The concentration of mercury in the air depends not only on temperature but on a series of other conditions, such as the known relationship established between concentrations of mercury vapors and their distance from a volatile surface of mercury. According to the data of Renk*, air found above 0.5M2 from the surface of metallic mercury at a height of 5 cm about the vaporizing surface contains 1.86 mg mercury vapor in one M3, at a height of 30 cm -- 1.26 mg, at a height of 100 cm -- 0.85 mg.

Vaporization intensity of mercury depends to a significant degree upon the movement of air over the vaporizing surface. Thus, according to the data of V. G. Matsak and L. K. Khotsyanov (1959), the vaporization of mercury in still air depends on diffusion and occurs significantly slower than in the presence of convection currents.

On looking at specific quantities which characterize the meaning of the coefficient of diffusion (D) for vapors and substances diffusing in the air, attention is called to the high coefficient of diffusion for mercury (D at zero degrees C equals 0.1124) in comparison with analogous parameters for volatile organic substances having the same molecular weight.

Of significant hygienic interest is the presentation of data, characterizing the vaporization rate for mercury and permitting the determination of air volume requirements in order to reduce the content of mercury vapors in premises to the level of the maximum permissible concentration. These calculated data, according to V. G. Matsak and L. K. Khothasov, can be obtained if known physical relationships for the vapor diffusion rate of a substance is obtained for the determination of relative vaporization rates. It is accepted that, at the surface of a substance, there is an especially thin layer of air, 100% saturated with the vapor of the substance at its surface temperature. How can we obtain this related data? For processes of vaporization of toxic substances in closed premises, especially in winter, where doors and windows of the premises are closed, one considers the characteristically insignificant movement of air above the vaporizing site.

The vaporization of mercury in slowly moving or still air proceeds slowly; if occurring in the absence of ventilation can build up relatively high concentrations of mercury vapors. The mercury is removed especially slowly (frequently after spillage) from such "premises" and premises at which there is no heat source producing air movement. A more marked effect is noted when mercury vaporizes from open surfaces of instruments, or devices, laboratory apparatus, glass cylinders, and so forth. In these cases, under the effect of the open surface, mercury vaporizes comparatively intensively even in weak air currents. Besides that, to obtain complete inactivity of air under conditions as on a mirror, the vaporization of mercury does not occur in relatively deep vessels or only with the greatest difficulty.
Further, there is a relationship between the concentration of mercury vapor in the air and the purity of vaporizing mercury. Pure metallic mercury is easily pulverized and disintegrates into separate very fine globules, which, in toto, compose a significantly higher surface of evaporation than the same quantity occurring as an ordinary compact mass. This is a consequence of the high surface tension and low viscosity of mercury. If we postulate that 5-10g of mercury happen to disintegrate on a laboratory table and forms on it a multitude of globules with a diameter of 0.1 mm, the surface of all of these would constitute about 1.5-3 m². Obviously, such a significant open surface of mercury can cause the constant and prolonged introduction of mercury into the air of a site, building up high concentrations in the air of a work zone.

Mercury belongs to the group of substances with high molecular weight - 200.61, the vapor of which is heavier than air (usually 7 times). In connection with this among hygienists there is the widely-held opinion that mercury vapor present in the air of a work shop, being noticeably heavier than it, sinks down and accumulates in the lower zone. Such a theory about the continuous prolonged (in all cases) inherent capability of mercury vapor, as with other high molecular weight substances, "to fall", determines as a rule, the relative hygienic principles for solving the problems of a choice of site for taking air samples, and also the zone of recovery (fraction) of contaminants of the introduction "of a current" of pure air through ducts into these sites with sensible ventilation. There is such a wide distribution not only among hygienists, but among sanitary technology, that there is insufficient foundation for this data. Therefore one can agree with the conclusions of V. G. Matsak and L. K. Khotsyanov that, "heavy vapors of substances are only slowly removed from the air during vaporization without heating when the pressure of saturated vapor at the vaporization temperature is high". In such cases, when the vapor pressure of a substance at the vaporization temperature is low, a noticeable displacement of the air does not occur. Consequently, from this, it is impossible to expect mixing of vapors of this substance in the lower zone. Thus, the sinking of air saturated with mercury vapor at a temperature of 20°C, is almost insignificant. This illustrates the low vapor tension of saturated mercury vapor at this temperature.

From other physical and chemical properties of mercury we stop short at the ionization potential, and also we observe certain peculiarities occurring in its inorganic and organic derivatives and the conditions of their use in everyday practice.

IONIZATION POTENTIAL.
Mercury has a high ionization potential (10.39 electron-volts). From this is connected the property of mercury metal to separate from its various compounds, that is, to transform to its atomic form. This property is one of the most characteristic for mercury and explains the cases of finding it in a native state in nature. The high ionizing potential of mercury explains the capacity of mercury to form various compounds with active reagents, such as oxygen, acids, etc.

INORGANIC MERCURY COMPOUNDS.
From the hygienic point of view mercuric chloride is of greatest interest, also sulfides, and nitrates. Notice also that we discuss these compounds in order of their lethal toxic significance - from the most toxic to the least toxic.

Mercuric chloride, corrosive sublimate - (HgCl₂)
This compound is a white crystalline powder. Its specific gravity is 5.44, melting point about 277°C, boiling point 303°C. It has a metallic taste. It precipitates protein. Various organic substances, especially under the effect of heat and light, react with mercuric chloride, yielding calomel. Mercuric chloride is mainly used as a strong antiseptic agent. Thanks to its good solubility and high degree of dissociation it is number one of all inorganic compounds of mercury which display a disinfectant power. Mercuric chloride dissolves in liquids, which makes it easy to penetrate tissues. Its antiseptic action is caused not only by the action of free mercury ions, but also by the effect of complex compounds, formed through the combination of metallic salts.
Mercuric chloride sublimes easily. It is soluble in cold (6.6% at 20°C) and hot (56.2% at 100°C) water, acids, especially acetic, and alcohol (33% to 25°C), ether, acetone, pyridine in salt solution with the formation of a complex compound HgCl₂· NaCl. Its water solutions give acid reactions but upon the addition of NaCl the reaction becomes neutral. It is weakly dissociated. In light, especially in the presence of organic compounds, it reacts easily with metallic mercury and calomel. The results of the reaction are a mixture of mercuric sulfates and sodium chloride (NaCl) which upon heating yield:

\[
\text{HgSO}_4 + 2\text{NaCl} \rightarrow \text{Na}_2\text{SO}_4 + \text{HgCl}_2
\]

To prevent the formation of Hg₂Cl₂, a small quantity of manganese dioxide was added to the mixture. The calomel formed in this way sublimes. Another method of doing this is to dissolve mercuric oxide in an acid salt or react a surplus of chlorine with metallic mercury, heated almost to its boiling point.

To the group of soluble inorganic compounds belong also the above mentioned oxides and suboxides of mercury salts of nitric acids.

Nitric suboxide of mercury -- [Hg₂(NO₃)₂·2H₂O]
This compound is a white crystalline powder. Its specific gravity is 4.78, melting point ~70°C. It dissolves in water in small quantities, it hydrolyzes easily:

\[
\text{Hg}_2(\text{NO}_3)_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_3 + \text{Hg}_2(\text{OH})\text{NO}_3
\]

It dissolves in nitric acid and hot carbon disulfide. It is obtained by the reaction of mercury with cold nitric acid.

Nitric oxide of mercury is a colorless crystalline powder; soluble in nitric acid and acetone. Hydrolyzes in water, after which it forms the basic salts:

\[
\text{Hg(NO}_3)_2 + \text{H}_2\text{O} \leftrightarrow \text{HNO}_3 + \text{Hg(OH)NO}_3
\]

\[
2\text{Hg(NO}_3)_2 + 2\text{H}_2\text{O} \leftrightarrow \text{Hg}_2\text{(OH)NO}_3 + 3\text{HNO}_3
\]

It is obtained by the reaction of mercury or mercuric oxide in hot nitric acid (concentrated). Its specific gravity is 4.3; its melting point ~79°C.

Mercury Fulminate [HgC₂N₂O₂]
It is obtained by the solution of metallic mercury in nitric acid in the consequent reaction of the obtained solution with ethyl alcohol. It is a hard crystalline substance. It detonates easily upon heating, striking or friction. The decomposition of mercury fulminate proceeds according to the following equation:

\[
\text{HgC}_2\text{N}_2\text{O}_2 \rightarrow \text{Hg} + 2\text{CO} + \text{N}_2
\]

It is used as an initiating substance in blasting caps.

Mercuric sulfide, cinnabar (HgS).
Cinnabar occurs in nature as an ore, it is basically the most widely distributed mercuric material from which mercury is obtained. It contains 86.2% mercury and 13.8% sulphur; it commonly contains impurities of clay, iron oxides, bituminous materials. Two forms are known; a black amorphous substance and a dark red crystal. Its specific weight is 8.0-8.2; hardness 2.0-2.5.

Cinnabar is quite resistant to atmospheric agents, and even in rare cases transfers to native mercury, calomel or mercuric oxychloride. Its boiling point at normal pressure -- 580°C. Its solubility in water is insignificant; in nitric acid salts it is insoluble. It dissolves in 2N HCl upon boiling. Artificial cinnabar is obtained in the process of prolonged grinding of corresponding quantities of mercury and sulphur or the precipitation of hydrogen sulfide from
solutions of mercuric oxide salts (black sulfide), and also upon grinding mercury with sulphur or K₂S₅ with consequent treatment with alkali (red sulfide). The heat of formation -- 109,000 cal/gm mol.

Mercury monochloride, calomel (Hg₂Cl₂). Calomel is obtained by heating mercury and mercuric chloride; reacting the acid salt on the soluble salt of mercury suboxide:

\[ \text{Hg}_2^{++} + 2\text{Cl}^- \rightarrow \text{Hg}_2\text{Cl}_2 \]

then sublimation from the mixture of a sulfate of mercury suboxide and cooking salt with the consequent washing of the sublimate to remove the mercuric chloride.

\[ \text{Hg}_2\text{SO}_4 + 2\text{NaCl} \rightarrow \text{Na}_2\text{SO}_4 + \text{Hg}_2\text{Cl}_2 \]

Mercury monochloride is a white crystalline powder. Externally it is almost identical with mercuric chloride. However, on grinding it takes on a yellow color, while mercuric chloride remains white. The specific gravity is 7.15; the melting point 302°C; the sublimation point about 310°C; the boiling point 383.7°C. Mercury monochloride is insoluble in water, alcohol, ether and dilute acids. It dissolves in boiling hydrochloric acid with the formation of mercuric chloride, and also in nitric and sulfuric acids. It decomposes in alkali releasing mercuric oxide.

To the water insoluble inorganic mercury compounds belongs mercury iodides and bromides, and also a series of other suboxides of mercury.

Solubility of the salts: From the hygienic and toxicological point of view the problem of the degree of solubility and dissociation is extremely important to the understanding of the effect on the organism of mercury salts because this property determines penetration and the degree of the subsequent toxic effect.

It is known that the effect of mercury compounds as protoplasmic poisons depend to a great degree upon the active effect of specific mercury ions upon the living cell. Evidently the greatest expression of toxic effect occurs with easily soluble and easily dissociated salts. Mercuric chloride, for example, is the most soluble and easily dissociated compound, and has a well developed bactericidal effect on micro-organisms; more than, say, the less soluble and less dissociable mercuric cyanides. Thus, the degree of toxicity, consequently, given the expression of antiseptic action of various mercury compounds is heterogenous. The degree of toxicity depends directly upon the solubility, the degree of dissociation and the concentration of free mercury ions. The toxic effect of mercury salts depends also in relative degree on the content in the surrounding medium of protein substances, in combination with which (these substances bind or precipitate mercury) mercury salts are absorbed. Cooking salt to a significant degree can dissolve these compounds, forming mercury soluble albuminates. Cooking salt can also convert insoluble mercury compounds to soluble ones.

In conclusion let us note that inorganic mercury salts are comparatively unstable. Metallic mercury can be separated from them by contact with a series of metals, for example, iron and reaction with various agents. At such working premises where production work with mercury compounds occurs, mercury vapor is often liberated.

ORGANIC MERCURY COMPOUNDS.

Mercury is an element distinguished by its abundant organic derivatives. Generally it displays, in comparison with the majority of metals, the closest relationship to carbon. This indicates the fact that organic derivatives of mercury are obtained most easily compared to organic derivatives of other metals and they are much stabler in comparison with the majority of known organometallic compounds. Among organic compounds of mercury one must note only those in which one atom of mercury binds directly (with the aid of one or two bonds) with a carbon atom. Organic derivatives of mercury differ from inorganic in that in their masking the actions of mercury ions; they do not give yellow mercuric oxides upon reaction with alkali; they do not precipitate protein and do not immediately react with ammonium sulfate. Organic mercury compounds have a
significant bactericidal effect. Further, the simplest of them, for example, mercurophene, in its effect on bacteria does not yield mercury chloride.

P.P. Shorygin (1910) stated that the toxicity of organic mercury compounds for higher animals were weaker according to their capacity to give typical mercury reactions. The author characterized organomercury compounds as "atoms of mercury, assigned to organic molecules". F. Withmor (1921) noted the presence of a relationship between a strong toxic effect and the characteristic of addition of organic residues to the valency of mercury. The author stated that so called symmetrical compounds, in which both valences of mercury bind with carbon, are less toxic than compounds having one carbon bond, and another with hydroxyl, chlorine, and thiosulfate groups. This explains why symmetrical organomercury compounds are very stable. The toxic effect of introducing them into the organism is connected with a splitting off of one radical and its subsequent transfer to the chlorine. The marked toxicity of diethylmercury, for example, lies in its formation in the organism of a new compound -- ethylmercuric chloride. Evidently, symmetrical mercury compounds ought to be unstable to a degree in order to produce their toxic effect. In the process of studying the chemical toxic properties of a variety of organomercuricals it has been shown that the most active are compounds of the type RHgX, where R is a benzene ring with or without substituted groups. X is a hydroxyl (OH), or a cyano (CN) group, or, possibly a halogen atom. In the latter case the activity of the compound increases from chlorine to iodine. There is a relation between the chemical structure of various organomercury derivatives and their degree of toxicity. Among them the most significance is attached to the structure of the radical characterizing the acid residue. Thus, among methyl- and ethylmercury compounds, the most toxic are the phosphates. After them come the chloride and cyano derivatives, and finally the toluolsulfates. Among the phenylmercuric compounds, the acetates are less and the nitrates more toxigenic than the chlorides. The substitution of a methyl or ethyl radical increases toxicity, and the substitution of a methyl for a phenyl lowers toxicity (about four to five times) (L. I. Medved', 1954). In modern times organomercury compounds are synthesized from hydrazones, aldehydes, and ketones, which react easily with mercuric acetate in aqueous solution at a temperature of 70-90°C (A.N. Nesmeyanov, O. A. Reutov, A. S. Loseva, 1956). Of compounds of this type the most important in a hygienic context are the ethylmercuric chlorides, methoxyethylmercuric acetate, phenylmercuric bromide, and phenylmercuric acetate. The wide use of these hygienic compounds as pesticides and fungicides (granosal, radosan, agronal and others), and complex acting compounds (mercuran, mercurhazane, have stimulated the most interest in them by domestic (S. I. Ashbel, 1964; V. Ye. Balashov, 1964; G. A. Belonovskho and coauthors, 1967; N. P. Borisenko, 1967; L. I. Medved', 1961; N. D. Mukhtarov, 1967; I. M. Trakhtenberg and co-authors 1966; A.R. Uvarenko, 1968; and others) and foreign scientists (I. Barnes, I. Magos, 1968; I. Gage, 1964; and others).

Ethylmercuric chloride (C₄H₇Hg) is a white crystalline substance with a boiling point of 192.3°C. Its solubility in water at 20°C is 1.4 x 10⁻³ grams in 100 grams H₂O, it dissolves easily in hot alcohol and in 10% NaOH solution (in cold to 20%). It is quite volatile, as a result of which at room temperature and lower it can escape into the air as vapor. According to the data of M. A. Trotsenko (1958), the volatility of vapor of ethylmercuric chloride at 20 degrees and 21.5 degrees is about 11 mg/m³ and 21 mg/m³. Almost identical results (12 mg/m³) at 20°C were obtained by Charley and Skinner (1955), who determined ethylmercuric chloride according to the frequency of vibration of a quartz crystal in vacuum. According to the data of A. Swensson (1952), vapor pressure of ethylmercuric chloride at 20°C is equal to 300 x 10⁻³ mmHg standard. This explains the initial effectiveness of a group of pesticides - granosal (NIVIF-2), mercurane, cerezane and others.

Ethylmercuric Phosphate (C₄H₇Hg).3(PO₄) is a white crystalline substance with a melting point of 178-179°C. It dissolves well in water and alcohol. It is somewhat hygroscopic. It decomposes under the influence of acid rather more slowly than through ignition. Splitting off an organic residue occurs only after prolonged heating with nitric acid. The specific gravity is 1.5. Ethylmercuric phosphate can be decomposed by halogens,
reactions with which occur in the cold in the course of one to two hours. Reaction can be represented according to the following equation:

\[2(C_2H_5Hg)3PO_4 + 6X_2 \rightarrow 3HgX + Hg_3(PO_4)\]

Ethylmercuric phosphate volatilizes and mixes with air even at room temperature.

**Methoxyethlymercuric acetate**

\[CH_3OCCH_2HgOCOCH_3\]

is a white crystalline substance containing 62.8% mercury. The vapor pressure of methoxyethlymercuric acetate at 20°C is \(13 \times 10^{-6}\) mmHg, standard. It is the active principle of the fungicide radosan.

**Phenylmercuric bromide**

\[C_6H_5HgBr\]

**Phenylmercuric Acetate**

\[C_6H_5HgOCOCH_3\]

are white crystalline powders which contain about 56 and 60% mercury. The vapor pressure at 20°C is \(6 \times 10^{-7}\) mm Hg, standard. They are the active principal in the fungicides argronal, ruburone and leytosan.

**Diethylmercury**

\[Hg(C_2H_5)_2\]

is a colorless liquid with an unpleasant odor. Its specific gravity is 2.55; its boiling point is 195°C. This compound is almost insoluble in water, is weakly soluble in alcohol, and dissolves easily in ether. It is obtained by the reaction of sodium amalgam in ethyl bromide.

In connection with a survey of these properties common to the organic derivatives of mercury, one should pay attention to the process of their industrial synthesis in the air of work zones which can simultaneously liberate vapors of organomercuricals and vapors of metallic mercury. Often in the air of industrial premises vapors of mercury dichloride are detected. This occurs on the one hand from peculiarities of the technology and synthesis of the indicated compounds and on the other from their definite volability.

This is a very brief survey of the physical and chemical properties of mercury, its inorganic and organic derivatives, which we consider advisable to discuss before dealing with basic data on the toxicology of mercury, industrial hygiene for its production and laboratory uses, of the presence of mercury in biological substrates and its distribution in the environment.

**Some Geochemical Data on the Content of Mercury in Objects in the Environment**

Specialists, working in the field of industrial studies in the geochemistry of determining chemical substances, concluded that the meaning of geochemical elements, that is, the laws determining distribution and dissemination in the earth's crust can be directed in a more rational path by new discoveries and further analysis of the data on a given substance. According to V. I. Vernadskiy (1934), geochemistry studies the atoms of the earth's crust, their history, distribution and movement in space and time, their genetic relationships. A. A. Saukov (1940) undertook basic studies in the geochemistry of mercury, in the course of which he determined the concentration of mercury not only in various minerals, mine tailings, ores, soils, etc. but also in objects in the hydrosphere and atmosphere, and in organisms, etc. The significance of these data are very important. In studying the distribution of mercury in nature, its content in various plants and animals, its absorption by highly dispersed systems, etc, A. A. Saukov made the foundation for the expansion of hygienic norms for the content of mercury vapor in the external environment, the truth about the occurrence of mercury in human and mammalian organisms, and about its presence in various organs and systems.
As the chemical elements isolated from ores will increase, mercury lends itself to multiplex hygienic evaluation of its scale and route of migration which appears below: Data on the World Production of Mercury between 1500 and 1967
(Prepared by S.M. Mel'nikov)

As evident from the preceding data and also from later materials, the production of mercury, especially in later years, increased significantly so that truly one cannot deny the hygienic importance of it in our external environment.

One of the most important problems in the hygienic evaluation of mercury content under natural environmental conditions is that the quantity of mercury present in the atmosphere of inhabited places.

The continued presence of mercury in the atmosphere is caused by the high volatility of its vapors which we have explained in detail above. How do these direct sources contribute mercury to the atmosphere? What explains the fact that under natural conditions the air above forests and fields contains about 0.00001 mg/m³ of mercury?

First of all note that the occurrence in the atmosphere of mercury vapor occurs as the result of direct contact of native liquid mercury with the atmosphere. M. M. Saukov notes that often in cinnabar deposits native metallic mercury is not discovered not only because it is not observed, but because of its speed of vaporization is higher than its rate of formation. Also mercury occurs in the atmosphere through the eruption of volcanoes, because magma always contains some quantity of mercury. The presence of mercury in the atmosphere is connected with its isolation from mine sources of juvenile origin, and from jets, occurring at the surface of the earth. It is possible that it is discharged into the atmosphere together with water vapor during evaporation from the hydrosphere. A. Stock and S. Cucuel (1934) conducted experiments to determine mercury directly in atmospheric air and under conditions which excluded the possibility of contamination of the air by mercury used in industry. Towards this goal the authors carried out two experiments, using a system of cooling liquid air, on 3.5 cubic meters of air, In both the first and second case they detected 0.00003 mg mercury. They undertook a control (blind) experiment with these reagents and obtained the presence of 0.00001 mg mercury. Thus they discovered quantities throughout five tests of 0.00001 - 0.00002 mg when each of these tests used a 300-600 liter air sample.

From these data, A. Stock and F. Cucuel came to the conclusion that the content of mercury in the atmosphere approached the limits

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some data on the scale of mercury production</td>
</tr>
<tr>
<td>Years</td>
</tr>
<tr>
<td>1500-1600</td>
</tr>
<tr>
<td>1601-1700</td>
</tr>
<tr>
<td>1701-1800</td>
</tr>
<tr>
<td>1801-1900</td>
</tr>
<tr>
<td>1901-1946</td>
</tr>
<tr>
<td>1947-1967</td>
</tr>
</tbody>
</table>

of sensitivity of the method and took up no more than 0.00002 mg/m³. An interesting connection based on this analysis was put forth by A. A. Saukov. Corresponding calculations made by the author indicated that if one takes as a basic proposition the unidirectional reaction formation of all mercury compounds of metallic mercury, then evaporate them into the atmosphere the content of them in the air would be:

\[
\frac{1.57\times10^{12}}{7.875\times10^{18}} = 0.2 \times 10^{-6} \text{ m}^3 = 2\times10^5 = 200 \text{ pm}/\text{M}^3 = 0.2 \text{ M}^2/\text{A}
\]

1.57.10^{12} 
7.875.10^{18} M3
Why is the actual content of mercury in the atmosphere much lower than calculated? This can be explained first of all by the presence of reversible processes as a result of which mercury is transformed from its gaseous state to the solid and in this way is removed from the atmosphere. For the hygienist the point of these processes have a determining interest, in that they determine to a significant degree, the content of mercury in such objects in the external environment, as the soil, water, and plants. These processes represent, in general, the solution of mercury in the water of the hydrosphere, in rain water, sorption of mercury vapor by highly dispersed systems, especially in soils, etc.

Analysis of the sorption of mercury vapor occurring under natural conditions has direct practical significance for hygienists. In a given case the relationships connected with the sorption of mercury vapors observed not only from the position of interest in the general characteristics of mercury distribution in objects of the external environment but also from the point of view of devising more active sorbents for mercury vapor. The research of Ye. V. Alekseyevsky (1933) showed that one of the very powerful absorbents of mercury was active manganese dioxide $\text{MnO}_2$. The grounds for undertaking these studies were the observation under natural conditions of processes in which the sorption of mercury vapors occurs. It is especially intense in hydrated manganese oxides. From these results, Ye. V. Alekseyevsky (1933, 1937) subsequently recommended activated manganese dioxide as a specific mercury vapor absorbent. Additionally, the author also studied the capacity and degree of mercury absorption of a series of substances (activated charcoal, activated alumina, cobalt oxide, hopcalite and others). Consequently the mercury vapor absorption under ordinary natural conditions is one of the factors determining its occurrence in nature as a shifting ratio between mercury, found in the atmosphere, on the one hand, and mercury in the lithosphere on the other. An analogous event takes place between mercury, found in the atmosphere and mercury contained in the hydrosphere. And here an important place is occupied by the sorption of mercury from solutions of certain highly dispersed (at the moment of formation) colloidal systems (clay deposits, iron and manganese ores, etc.). Besides that, portions of mercury, dissolved in water, enter the atmosphere by means of evaporation. At that time a reverse process is occurring: mercury, found in the atmosphere, dissolves in the water, and therefore enters the hydrosphere together with rain water.

The preceding geochemical data on the occurrence of mercury in nature and on certain relationships connected with its migration and its content in various objects in the external environment, permits, on the one hand, a sufficient basis (from a natural background) to treat the results of hygienic observations on the content of mercury in the atmosphere, drinking water, food products, the air of industrial premises, etc. Another would be controlled evaluation of the presence of mercury in the human body, quantities, characterizing its content as a micro-element. Only with the knowledge of these data can we see the whole problem of the effect on the organism of small concentrations of mercury, exposing its hygienic significance, determining principles for solving basic problems, clearly establishing limiting quantities, which, being "small", appear by no means indifferent from the point of view of hygiene and toxicology. Finally, the above data in conjunction with materials of hygienic observations on the content of mercury in the surrounding human environment, are especially productive, permitting a determination and knowledge, uncovered by us for the understanding of "small" or "low" concentration, which cause those concrete quantities of mercury in the air which is signified by this term.

In the atmosphere of big cities mercury vapor occurs significantly more often than in rural places. This is caused not only by all the sites using mercury in various aspects of production releasing it, but also by the burning in cities of large amounts of coal, fuel oil, and other types of fuel containing mercury. Coal contains about 0.000001% of mercury, oil shale, 0.001%. The content of mercury in soot is significantly higher than in fuel.

Significant quantities of mercury vapor enter the air when metallic mercury is extracted from its ores in metallurgical plants, and also through the treatment of iron ores and the ores of nonferrous metals. Each ton of these ores contains
about one gram of mercury which can release into the atmosphere at metallurgical enterprises hundreds of grams of mercury daily (H. N. Tomson, 1949).

The atmosphere is also contaminated by natural and illuminating gases in which mercury occurs in the quantities of 0.005 mg/m³. According to data of A. Stock (1936), mercury contained in street dust of cities amounts to 0.000087%.

The mercury vapor content in the air of large cities in conditions where multiple sources of atmospheric contamination by mercury exist and purification of the effluents is practically nonexistent, varies from 0.0003 to 0.002 - 0.003 mg/m³. From the sources of such contamination of the atmosphere by mercury vapor, according to R. C. Leytes (1952), appear clouding gases from mercury furnaces, air from vacuum and vacuum flow pumps containing exhausts from mercury apparatus and instruments, air from exhaust hoods (closed) for the conduction of work with heated mercury, air from exhaust hoods in which work with uncovered mercury is undertaken, exhaust from general shop ventilation systems from places where "open" and "closed" work with mercury occurs.

Table 3 shows mercury vapor concentrations in air samples. The degree of contamination of the surrounding atmosphere with mercury vapor close to the contaminating source is determined not only according to the content of mercury in the output but by the volume of discharged air, which in turn depends on the scale and production conditions of "mercury" processes and operations. According to the data of I. L. Kurinniy (1964), the yearly discharge of metallic mercury into the atmosphere around a mercury plant is about eleven tons. An especially large quantity of mercury is discharged into the air of the surrounding atmosphere in the summer period, when in connection with increased temperatures, on the one hand, a significantly increased vaporization of mercury occurs and the air is increasingly saturated with mercury vapor. On the other hand, there is the difficulty in condensing mercury vapors from furnace gases.

Observations of Soviet hygienists revealed a comparatively high concentration of mercury vapors near plants engaged in the production of mercury, enterprises making mercury instruments, and other industrial sites, where in the air of working premises there is a continual occurrence of mercury (Table 4).

From data in the table it is evident that industrial discharge of mercury vapors leads to very intensive contamination by them of the atmosphere. It is important to note that, at a distance of 1,000 - 2,000 meters from a site where mercury is used (in a few cases, despite the presence of devices for scrubbing mercury vapors), it occurs in the atmosphere in concentrations many times those encountered in ordinary (natural) conditions. The occurrence in the atmosphere of industrial discharges of mercury cause not only significantly higher concentrations of it in the air, but contaminates objects in the environment. It is absorbed by soil, leaves of trees, and building materials. From studies of soils contaminated by mercury of industrial discharges it is shown that the greatest quantity of mercury accumulates on the earth's surface. At a depth of 20 cm the content of mercury can be measured in tenths of a milligram, at a depth of 50 cm in hundredths of a milligram, and at a depth of 1 meter only traces of mercury occur (A.N. L'dov (1939). According to the data of V. P. Melekhina (1959), in soil at a distance of 100 - 2,000 meters from the plant which makes mercury thermometers, there was noted a high content of mercury. According to materials of V.N. Kurnosov (1962), in soil of an industrial district where there are factories for the production of instruments containing mercury, a quantity of mercury was observed which exceeded its content in the soil of a controlled district. I. L. Kurinnyy (1964) in his dissertation discussed the hygienic characteristics of the atmosphere in a region where mercury plants were distributed and presented data on the determination of metallic mercury and its sulfide. Re showed that the content of mercury in the soil decreases the farther one gets from the plant; the quantity of cinnabar decreases significantly faster as compared to metallic mercury.

The indicated materials pertaining to the significant sorption of mercury by the soil leads to the conclusion that, in the determined conditions the soil can be a source of secondary contamination by mercury of the atmosphere, water sources, ground water and plants.
Secondary contamination by mercury of various objects in the environment and the subsequent desorption determines the possibility of a mercury cycle between industrial sites and the surrounding atmosphere (Figure One). In the present chapter note that at various distances (up to 3,000 meters) from industrial source of mercury in the air along with the contamination of soil, researchers observed the absorption of mercury onto building walls, the contamination of air of various dwellings, the presence of mercury in paints on internal walls of these houses, on roof surfaces, and in the leaves of trees.

In speaking of the contamination of external objects with mercury from industrial discharges, it is very pertinent, so to speak, to note the comparatively low concentrations, on the order of 0.0003 to 0.002 - 0.003 mg/m³. At the same time it is vital to clearly establish that such quantities of mercury contained in the air are by no means the "natural" concentrations of mercury which characterize it as a trace element. The presence of mercury as a trace element permits a true evaluation of quantities of it which occur not only in the atmosphere, but in the biosphere, for deeper analysis the hygienic significance of minimal concentrations of mercury, to establish corresponding hygienic norms for the content of mercury in the environment. The generalization by hygienists of contemporary data on the geochemistry of elements and the acquaintance of geochemists with materials on the content and presence of these elements in the environment, obtained by hygienists, can facilitate a real attempt towards the development of a new branch of hygienic science -- geohygiene.

In arguing and propagandizing the idea of geohygiene, N. V. Lazarev (1959, 1956) set forth its task as the study of all the changes in chemical composition and physical characteristics of the external layer of the earth's crust which has or could have in the future "significance for the hygienic properties on the surface of the earth as a medium of habitation for man". In the opinion of N. V. Lazarev, hygienists must frequently know the scale and route of migration of toxic elements produced in connection with the removal of these elements from minerals. The author explains this fact, that the absolute dimensions of a mixed mass in the external layer of the earth's crust under the effect of the industrial activity of man at the present time is such that it is possible to change significantly the characteristics of all regions of the earth.

In developing the conception espoused by N. V. Lazarev on the geo-hygienic significance of chemical factors in the human habitat by our use of mercury, it

### Table 3. Content of mercury vapor in the air (released into the atmosphere)

<table>
<thead>
<tr>
<th>Object of study</th>
<th>Concentration of mercury vapor in mg/m³</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke and gases from mercury factories (basic quantities of these gases are formed in cylindrical rotating furnaces).</td>
<td>7-20</td>
<td>V. A. P'yankov</td>
</tr>
<tr>
<td></td>
<td>22-100</td>
<td>M. L. Loyevsky</td>
</tr>
<tr>
<td></td>
<td>11-80</td>
<td>V. Ya. Vorontsovsky</td>
</tr>
<tr>
<td>Air from exhaust hood during work with heated and unheated mercury</td>
<td>0.006-0.01</td>
<td>V. N. Kurnosov</td>
</tr>
<tr>
<td></td>
<td>0.5-1.5</td>
<td>R. G. Leytes</td>
</tr>
<tr>
<td></td>
<td>0.05-0.20</td>
<td>R. G. Leytes</td>
</tr>
<tr>
<td>Waste gases from general purpose ventilators</td>
<td>0.01-0.1</td>
<td>R. G. Leytes</td>
</tr>
<tr>
<td></td>
<td>0.11-1.0</td>
<td>A. N. L'vov</td>
</tr>
</tbody>
</table>

| Gases formed in retort furnaces of mercury factories | 8-14                                   | G. K. Shilin                |
| Air from vacuum and flow vacuum pumps              | 0.7-8.0                                | R. G. Leytes                |
|                                                     | 5-8.0                                  | N. G. Polezhayev            |
|                                                     | 0.74-2.72                              | According to data of the Scientific Research Institute for the Industrial and Sanitary Purification of Gases |
| Air from vacuum and flow vacuum pumps              | 0.006-0.01                             | V. N. Kurnosov              |
has been shown that at the present time the correct study of mercury and its hygienic and toxicological evaluation is from the point of view of geohygiene (I. M. Trakhtenberg, V. P. Yerogov, M.N. Korshun, 1968).

TABLE 4

<table>
<thead>
<tr>
<th>Distance from the site in meters</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. N. L. Voronkov, 1959</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-50</td>
<td>0</td>
<td>0.006</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>75-100</td>
<td>0.002</td>
<td>0.066</td>
<td>0.003</td>
<td>0.002</td>
</tr>
<tr>
<td>150-200</td>
<td>0.0015</td>
<td>-</td>
<td>0.0009</td>
<td>0.0003</td>
</tr>
<tr>
<td>250</td>
<td>-</td>
<td>-</td>
<td>0.0025</td>
<td>0.001</td>
</tr>
<tr>
<td>300</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.001</td>
</tr>
<tr>
<td>400</td>
<td>-</td>
<td>0.0004</td>
<td>-</td>
<td>0.0035</td>
</tr>
<tr>
<td>500</td>
<td>-</td>
<td>-</td>
<td>0.0015</td>
<td>-</td>
</tr>
<tr>
<td>800</td>
<td>-</td>
<td>0.0004</td>
<td>-</td>
<td>0.003</td>
</tr>
<tr>
<td>1000</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>1200</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 1

MERCURY CYCLE IN THE ATMOSPHERE

1. Industrial enterprise or other production source through which the air is contaminated with mercury.
2. Laboratory in which work with mercury is carried out.
4. Waste Gases
5. Reservoirs
6. Plantings
7. Soil
Particular attention should be focused on mercury as a factor exercising influence on the state of health of the population under conditions of the mercury biogeochemical province. We come now to the data of V. P. Yerogov (1966, 1967) obtained as a result of studies undertaken in the Gorno-Altay Autonomous Region where many ore bodies are located and there is intensive extraction of mercury from ores.

According to his data examples of different soil types from this province contain mercury within the limits 0.03 - 1.2 mg/100g., and in the control region, 0.004 - 0.12 mg/100g. The mercury level in water sources is indicative of its concentration in the external medium and is about 0.002 - 0.03 mg/l. The quantity of mercury in the atmosphere also exceeds significantly its content within the limits of mercury deposits and composes 0.007 - 0.13 mg/m3.

Upon analysis of general morbidity (based on published data) it was established that among people who had lived a long time within this region, indicators were significantly higher than among persons living in control regions (from 10.7 - 27.5%). There was a higher morbidity level in a majority of nosological forms: infectious diseases, ear, nose and throat diseases, diseases of the respiratory and hematopoietic organs, of the kidneys and urinary tract and of the mouth and teeth.

The number of people with dental caries in the region studied is up to 10.4% higher than in the control region; the difference in susceptibility of the groups to caries increases with age: from 4.0% in pre-school age children, to 8.6% in school children and to 18.7% in adults.

Interesting data have been obtained on the state of the thyroid gland. The study was done because most of the Gorno-Altay Region is known for the low concentration of iodine in its soil and water. This exclusion constitutes a geochemical province. A high Percentage of goiter is noted in both iodine poor and iodine rich regions of the biogeochemical province. In contrast to other places in the Gorno-Altay where a diffuse form of goiter prevails, populations at points in the mercury province are most often affected by nodal and mixed forms (72.9%). Another feature of endemic goiter in this location as opposed to endemic goiter in the rest of the Gorno-Altay is the unusual number of people afflicted with hyperthyroid goiter. Note also that as a result of iodine prophylaxis among schoolchildren who lived in regions with a low iodine content, the number of persons with goiter decreased from 54.0% to 29.8% in three years at the same time that analogous measures among schoolchildren of the geochemical province were almost ineffective: The percent of persons suffering from goiter rose from 40.0% to 43.9% in that time.

In determining the mercury content in the urine of persons living in the biogeochemical province, it was established among pre-school children -- 0.014 mg/l, among schoolchildren -- 0.021 mg/l, among the adult population -- 0.033 mg/l. This leads us to state that indicated quantities exceed by far the mercury content in the urine of persons having no contact with mercury or its compounds.

Thus, under the conditions of the mercury biogeochemic province and increased content of mercury in objects in the external environment determines the state of health of the population inhabiting these regions.

Mercury as a Bioelement

The presence, continual circulation and migration of mercury in the human environment determines its continued presence in a variety of biological substrates. Mercury belongs to the series of trace elements that is, those chemical substances which are found in plant and animal organisms in concentrations on the order of thousandths or hundred thousandths of a percent.

It is known that of 70 trace elements discovered up to the present time we have data on the biological significance of only 35. The discovery of the possible physiological significance of mercury as a trace element or the effect of its absence from the hygienic point of view is an extremely important task. The necessity of solving this dictates the principal need of determining the
"physiological norm" for mercury content in various biological substrates of the organism (organs, blood, saliva, urine, feces, etc.), food products, plants and so on. Knowledge of this "norm" allows hygienists a more basic orientation for the evaluation of the degree of risk of concentrations of mercury in the bodies of workers and to characterize the effects of a series of quantities which come to mind as "diagnostic". An attempt at such analysis has been undertaken already by A. Stock (1934). It agrees with data obtained by the author and his co-workers together with cooperating laboratories that man takes in about 0.005 mg Hg daily. About the same amount is excreted daily by the healthy person. Table 5 presents data on mercury content in food products.

A. Stock and F. Cucuel (1934) found relatively high concentrations of mercury in the bodies of estuaring and marine fish and in marine algae. After many observations A. Stock (1940) stated that traces of mercury occur in excreta of persons who have never had contact with mercury and that their blood, urine and feces contain insignificant quantities of mercury (on the order of 0.003 - 0.007 mg/l of blood). In his conclusions the author noted that the total mercury content in the human organism varies within the limits of 0.0001 - 0.001 mg/100g of fresh tissue. According to A. Stock, under ordinary conditions the mercury sources for the body are food products and dust discharges which contain traces of this metal. According to his data, persons who have not had daily contact with mercury excrete urine containing up to 0.0005 mg mercury and feces containing up to 0.01 mg.

S. Teisinger (1953) and other workers observed the healthy man can excrete 0.008 - 0.017 mg Hg/1 of urine.

I. Bodnar, Od. Szep and B. Wespremy (1939) having determined mercury in organs taken from human cadavers who in life had had no contact with mercury commented on the insignificant quantities of mercury in human organs and tissues. L. Brigatti (1949) stated that the limits of normal mercury content in the human body were 0.05 mg/100 g. According to the author the largest quantity of mercury occurs in the liver, less in the lungs and brain and still less in the heart.

Spectrometric studies revealed that in dry tissue from humans who have had no contact with mercury, the following concentrations occur:
in the kidneys -- 0.05 mg%, in the liver -- 0.37 mg%, in the spleen -- 0.12 mg%

### TABLE 5

**The content of mercury in food products (A. Stock and F. Cucuel, 1934)**

<table>
<thead>
<tr>
<th>Products of plant origin</th>
<th>Amount of mercury in mg/100g of product</th>
<th>Products of animal origin</th>
<th>Amount of mercury in mg/100g of product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried peas</td>
<td>0.0012</td>
<td>Pork</td>
<td>0.0006 - 0.0013</td>
</tr>
<tr>
<td>Dried beans</td>
<td>0.0046</td>
<td>Veal kidney</td>
<td>0.0023</td>
</tr>
<tr>
<td>Potato</td>
<td>02 - 0.0004</td>
<td>Beef kidney</td>
<td>0.0067</td>
</tr>
<tr>
<td>Apples</td>
<td>0.0004</td>
<td>Milk</td>
<td>0.006 - 0.0012</td>
</tr>
<tr>
<td>Rye flour</td>
<td>0.0036</td>
<td>Butter</td>
<td>0.0002</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>0.002</td>
<td>Eggs</td>
<td>0.0022</td>
</tr>
<tr>
<td>Beer</td>
<td>0,00007 - 0.0014</td>
<td>Codfish</td>
<td>0.0024 - 0.0082</td>
</tr>
<tr>
<td>Cocoa butter</td>
<td>0.006</td>
<td>Flounder</td>
<td>0.01 - 0.011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beluga</td>
<td>0.0065 - 0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mutton fat</td>
<td>0.028</td>
</tr>
</tbody>
</table>

According to I. G. Fridlyand, insignificant quantities of mercury in excreta of healthy humans are caused by its uptake along with certain food products by the body. Interesting materials were obtained by F. Borinskiy (1931). He studied urine and feces of persons who had had no contact with mercury and in 51% of the cases found mercury present in quantities varying from 0.005 - 0.01 mg. In
twelve of the eighteen children studied, the daily voidance of urine and feces yielded from 0.00008 - 0.0007 mg mercury. P. Borinskiy also studied food products and found mercury in them (Table Six).

The author concluded on the basis of his obtained data that the 0.01 mg mercury content in the daily urine output was normal and therefore was not significant.

TABLE 6

<table>
<thead>
<tr>
<th>Product name</th>
<th>Amount of mercury in mg/100g of product</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread</td>
<td>0.0001</td>
</tr>
<tr>
<td>Dark bread</td>
<td>0.00026</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.00008</td>
</tr>
<tr>
<td>Potato</td>
<td>0.00025</td>
</tr>
<tr>
<td>Beef</td>
<td>0.000028</td>
</tr>
<tr>
<td>Milk</td>
<td>0.000016</td>
</tr>
<tr>
<td>Carrots</td>
<td>0.000016</td>
</tr>
<tr>
<td>Fish</td>
<td>0.0004</td>
</tr>
<tr>
<td>Herring</td>
<td>0.00047</td>
</tr>
<tr>
<td>Pork</td>
<td>0.000016</td>
</tr>
</tbody>
</table>

From the preceding data it follows that mercury, even in extremely minute quantities, is, as a rule, found in human organs and tissues. What kind of a biological role does it have as a trace element? In light of the well-known theory of the dissemination of trace elements (V. I. Vernadskiy, 1934; A. N. Vinogradov, 1950) it is difficult to conceive that the mercury found in the biosphere as a trace element penetrates the human body with air, water and food and remains for a long time in the blood, organs and tissues, does not have a biological significance.

Interesting studies in that direction have been undertaken in recent years by A. A. Nepesov (1955, 1958). He undertook the study of the principles and processes underlying the "physiological properties of mercury" in those concentrations encountered under normal environmental conditions and in the human body. In the opinion of A. I. Venchikov, (1947, 1957) which he expressed in the study of the physiological properties of trace elements one can distinguish two possible forms by their action in the living organism. One of these is the "pharmacotoxicological, having the property in relation to the intake concentration of either damaging protoplasm or denaturing proteins, and blocking various steps of enzyme processes", and the other, "biotypic, continually participating in the metabolism of substances necessary to the normal life function of the organism".

What are the results of the study of mercury as a bioelement? Research indicates that a really minute quantity of mercury (solutions of mercury dichloride, 0.003 - 0.125 mg%) have the capability of stimulating phagocytic activity of blood leucocytes in vitro and in vivo and to increase the intensity of heat exchange. In experiments on isolated frog hearts, mercury in the indicated concentrations has the property of "rendering toxic liquids (As a "toxic liquid" they used an extract obtained from products formed by "decomposing muscle") harmless on tissue and the same time could accelerate restoration of disturbed cardiac function". Simultaneously they noted increased viability of the frogs who had been poisoned by toxic liquids and who had subsequently received 0.125 mg2 solutions of mercury chloride. Further experiments on guinea pigs poisoned with diphtheria toxin showed the detoxifying properties of mercury chloride administered every two hours for two days and then hourly for the following three days (0.001 mg). At the same time all guinea pigs who had received a lethal dose of diphtheria toxin died, but among animals who had received simultaneous doses of mercuric chloride, no deaths occurred.
Experimental evidence on mercury as a bioelement published by A.A. Nepesov indicates that it is an agent that stimulates phagocytic activity and metabolic intensity. Based on this data one can theorize that mercury as a bioelement participates in physiological processes connected with detoxication.

Separate observations on the detoxifying capability of heavy metal salts (copper, zinc) in microelement concentrations indicate that they participate in intracellular redox processes (A.I. Venchikov). One should be cautious in attributing the same properties to "physiological" concentrations of mercury.

Yet the preceding materials indicate that mercury can exert a beneficial stimulating effect on the course of certain physiological processes.

In recent years there has been more and more data on the effects of metals as trace elements on enzyme reactions in nucleic metabolism. It has been established frequently that mercury ions and ions of a series of other metals (Mg++, Ag+, Co++, Ni++) protect messenger RNA from the effects of RNAase (B. Singer, H. Frankel-Conrat, 1962; S. Nishimura, G. D. Novelli, 1963). The effect of mercury on the thermal stability of RNAase has also been established (S. Stocks, 1961).

Changes in viscosity and absorption spectra of high polymer DNA solutions depend on the presence of certain metal ions, in this case, mercury. It is known that DNA molecules in reactions with HgCl2 decrease significantly and, under the effect of bound mercury reagents, increase (S. Katz, 1958). Accordingly one can say that complexed metal ions, particularly mercury, in reactions with nucleic acids produce reversible changes in the physical properties of the latter and that study of these reversible reactions "can have great significance in explaining the biological function of nucleic acids" (M. Ya. Shkol'nik, 1963) and can additionally elucidate the role of metals as bioelements.

Mercury has another character in concentrations which exceed those normal for human organs and tissues. In these cases the border between the "physiological" and nonphysiological" effect of mercury gradually begins to disappear in its concentration in the environment. It rises and it gradually loses its significance as a trace element and begins to exert its effect as a toxic substance.

CHAPTER II

TOXICODYNAMICS OF MERCURY AND ITS COMPOUNDS: ENTRY ROUTE OF MERCURY INTO THE BODY

The picture of mercury intoxication, its character and degree of expression, is often determined by what route mercury and its compounds enter the body. N.Y. Lazarev (1938) points out that the problem of entry routes of industrial poisons has important practical significance since the type of prophylactic measures are directly dependent on possible routes of entry into the organism of one or another toxic substance. The latter, depending on the prevailing physical conditions, can penetrate the body by various routes.

Under production conditions the basic significance is held by the entry via the respiratory tract of mercury and its compounds in the form of dust and vapor, caused on the one hand, by the high volatility of mercury and its compounds and, on the other, the discharge into the air of the toxic fumes from mercury production. Cases in which, under production conditions, mercury and its compounds commonly penetrate the organism in a form which can be quickly ingested and absorbed (vapors and finely dispersed particles), create an opportunity for the manifestation of a toxic effect.

Mercury vapor, entering the respiratory tract, can be taken up during most of its journey by the mucous membranes. I. G. Gel'man (1935) stated that mercury vapor is easily absorbed by the alveolar endothelium.

Mercury vapor is absorbed by the lungs if it is at or slightly below body temperature. In case the mercury vapor temperature is higher than that of the
human body, mercury is not fully absorbed by the lungs. In that event part of the mercury vapor is retained by the upper respiratory tract, partly absorbed there and partly entering the gastrointestinal tract.

C. Gothlin (1911) considered that mercury vapor was completely removed from the air by the lungs if the concentration did not exceed 0.25 mg/m³.

Under production conditions, the entry of mercury into the body of workers through the respiratory tract is of known significance. From toxic dusts of mercury compounds, formed in the working process, mercury droplets setting on dust particles or condensing out of the vapors, can deposit in the upper respiratory tract and from there be swallowed into the stomach. Often mercury penetrates the body (the GI tract) while eating via dirty hands.

Under production conditions mercury and its compounds enter the body through the skin and mucous membranes usually in insignificant quantities. The actual possibility of such entry cannot be ignored. Especially significant is the comparatively wide use in industry and in medicine of a variety of mercury antiseptics.

A. M. Veger (1939) in the literature called attention to the case of a woman who, for six years rubbed an ointment containing mercury into the skin of her face and developed acute mercury poisoning. A. V. Stepanov (1947) noted the possibility of poisoning through the use of large doses (10-15 grams) of mercury sulfide ointment.

It is assumed that metallic mercury enters the hair follicles, sebaceous and sweat glands as a result of reactions with fatty acids yielding soluble compounds which can be absorbed. Mercury enters through damaged skin somewhat easier.

Data on the possibility of poisoning via the intake of mercury through the GI tract is contradictory. I. P. Kravkov states that metallic mercury alone, taken internally, does not produce poisoning; E. Starkenstein (1931) also considers that the intake of liquid metallic mercury has almost no toxic effect because there is little possibility of its dissolving in the GI tract.

With reference to literature data, A. C. Litinskiy (1940) considers that the use of metallic mercury for invagination, gout, and kidney stones does not produce intoxication. Especially indicative is a case observed in the author's practice, where a young woman, attempting suicide, swallowed a kilogram of metallic mercury. For two weeks the mercury was observed in various sections of the intestine by x-ray. During this time no clinical symptoms of intoxication were observed.

E. Cholstein (1937) described an analogous case when mercury swallowed by a child was observed in the digestive tract by x-ray but no clinical symptoms of mercury poisoning appeared.

At the same time there is the observation (S. N. Sidorov, 1942) that metallic mercury entering the body by multiple routes in a highly disperse state can bring about intoxication.

Conversion and Circulation of Mercury in the Body

There are two points of view regarding conversion and circulation of mercury in the body. One postulates a dependence of the indicated changes on the state of the mercury taken into the body, another, on the contrary, states that mercury entering the body regardless of its route of entry and state, in the end is determined by a unique chemical change.

How mercury is adsorbed by the mucosa of the respiratory tract is almost unknown. It has been suggested that mercury entering the lung as a vapor, initially deposits there as a metal, and then undergoes further oxidation. P. Ye. Syrkina (1934), G. L. Sklyanskaya-Vasiliyevskaya (1938), P. Holzmann, A. Stock and W. Zimmermann (1929), confirmed, under experimental conditions, a
noticeable content of mercury in the lungs. Note also the experiments of E. Holzmann, who detected mercury in expired air.

There is another point of view which explains the adsorption of mercury in the lungs by stating that mercury vapor dissolves in fluid on the surface of the lungs and from there enters the blood as protein compounds — mercury albuminates. In this, corresponding law of solubility of gaseous substances in liquids determines the rate and quantity of mercury entering the blood; this depends on its relative concentration in air and blood.

Adsorption of mercury vapor by the lungs occurs quickly and fully. In a short time the adsorbed mercury enters the alveolar epithelium. Part of it is exhaled.

Absorbed mercury, entering the stomach, causes the solution of mercury compounds in sodium chloride facilitating their transformation into complex compounds, chloroalbuminates. The latter are large complex molecules, in which mercury preserves its ionized state and carries a positive electrical charge.

I. G. Gel'man (1935) states that the difference in toxic effect of mercury vapor, on the one hand, of metallic mercury and mercury salts, on the other, is explained by the heterogeneous state of mercury circulating in the blood. According to I. G. Gel'man and G. K. Derviza (1936), the reason for the specific effect of mercury vapor lies in its atomic-disperse state, guaranteeing rapid penetration of mercury through the respiratory tract to the blood. The author surmises that mercury vapor, after entering the blood, retains its atomo-disperse state for a short time. A concurring point of view is held by C. Biondi (1931).

The experiments of I.G. Gel'man and G. K. Derviz (1936) showed that if the blood is saturated with mercury vapor and pure air is bubbled through the blood, "free" mercury is observed therein. Apparently, only after a prolonged period of enzyme oxidation in the circulating blood does the "free" mercury combine with protein or salt molecules. The authors consider that atoms of mercury found in the blood are adsorbed by a protein molecule and are distributed on its surface. Later, "under favorable conditions this bond breaks and free atomic mercury can penetrate the cell and cause a toxic effect there". Simultaneously metallic mercury, having entered the blood, remains "toxically indifferent". The explanation of this is that particles of mercury, circulating in the blood, though not small, are nevertheless larger than the protein molecules. Upon entering the blood, they are covered by a protein film, which adsorbs on them, taking the role of a protective colloid. Apparently, this factor is responsible for the low toxicity of metallic mercury circulating in the blood.

A very indicative case is described by Umber (cited by A. N. L'vov, 1939). A young, female x-ray technician attempted suicide by injecting herself in the right ulnar vein with about 3 gm metallic mercury. Mild symptoms appeared (diarrhea, salivation, stomatitis) but were of short duration, during which characteristic neural disintegration was not observed. X-rays of the lungs revealed multiple mercury emboli and distinct droplets of mercury in the right ventricle and in the V. thoracalis lateralis.

Mercury salts, as noted, form complex compounds with proteins in the form of mercury albuminates circulating in the blood. Blood flow either carries mercury to a depot or to the separate organs where mercury albuminates split liberating ionized mercury as a salt (chloride or other).

E. Starkenstein, E. Rost, S. Pol (1931) consider that the effect of ionized mercury salts in the body is different from that of mercury vapor and that the course of poisoning is different in each case. They consider it improper to speak of mercury "in general" disregarding the difference in effects of its compounds.

The orthodoxy of this view is based on results of studying transformations of mercury in the body upon poisoning with organomercury derivatives.
P. Nerr (1887), investigating in animals the effects of organo-mercuricals (ethylmercuric chloride, ethylmercuric phosphate and diethyl mercury) showed that upon rapid intoxication, when the death of the animal occurs within two to three hours after receiving the preparation, organomercury compounds are still intact. In this case only traces of mercury are detected after prolonged presence in the organism (3-7 days after receiving the preparation) of a poisoned animal, larger quantities of mercury are observed along with intact ethylmercuric chloride. The authors maintain that during the action of organomercuricals initially the effects of the intact molecule is observed followed by the combined action of split-off mercury, the toxic effect of which becomes predominant. O. Müller (1929) and other scholars studying the action mechanisms of organometallic compounds, came to an analogous conclusion.

After analyzing the preceding data and comparing it with the results of his own observations, L. I. Medved' (1946) pointed out the difference in the action mechanism of inorganic mercury salts and their organic derivatives. Inorganic salts in the first moment of entry into the body form chloroalbuminates and are not adsorbed by the cells, acting on the excretory tract. Simultaneously, the organic compounds are adsorbed and retained in the tissues producing their toxic effect. Evidently, later, under the effects of various complex factors, organic compounds react with the body, change to chloroalbuminates, and after separating from them, exert the same effects as the inorganic salts. Consequently, the processes of mercury transformation in the organism depends upon the route and character of its entry. Organic mercury compounds and their vapors have toxicological features determined by the physical and chemical properties of mercury and its derivatives and by their chemical changes in the body. Therefore, remember that one mechanism underlies all traits and differences in the effects of mercury and its inorganic and organic derivatives, the presence in them of a thiol nucleus, the inactivation of functional groups (especially sulfhydryl) of cellular proteins.

The topography of mercury depots in the body, the dependence of infection of these or other organs on the degree of mercury accumulation on a background of intoxication -- all these problems are very pertinent from a diagnostic and therapeutic viewpoint.

The Distribution of Mercury in the Body and its Accumulation in the Organs

Data on the relative distribution and accumulation of mercury in the body is contradictory. Possibly this is explained by the difference in the introduction of the poison into the organism, and possibly by differences in the accuracy of methods used for the determination of mercury.

P. E. Syrkin (1934) investigating the organs of animals dead of mercury vapor poisoning, found a maximal deposition of mercury in the brain, kidneys, liver and heart. In the remaining organs mercury occurred in significantly lesser quantities. He noted the presence of the determining relationship between mercury content in the brain and kidneys: when significant quantities of mercury are present in the brain its content in the kidneys was insignificant or absent. Indicatively, when mercury is observed primarily in the brain the clinical picture of intoxication in test animals develops and progresses typically; the appearance of mercury poisoning develops distinctly. Simultaneously the presence of significant quantities of mercury in the kidneys somehow does not accompany symptoms of intoxication, excluding the finding of mercury in the urine and partial decrease in total urine output.

N. P. Kravkov (1928) points out that mercury is dispersed and deposited unequally in various organs; in acute poisoning it is found mostly in the kidneys, then in the liver and spleen, N. P. Kravkov emphasizes that the mercury content in the stomach and intestinal walls increases parallel with the degree of poisoning and therefore "the large intestine, the most contaminated, contains the greatest quantity of mercury and the stomach the least." I. G. Gel'man (1935) considered that mercury precipitates into the skeleton, liver, and to a lesser degree, the kidneys and bone marrow. N. V. Lazarev (1938) proposes that, in the body mercury deposits primarily in the liver and kidneys. He believes that mercury is retained in the liver for a long time. According to the author,
the retention mechanism of heavy metals in the liver is partly explained by the formation of compounds with nuclei, and partly by the reduction of heavy metals and their deposition in the Kupfer cells.

N. D. Rozenbaum (1933) in surveying the literature data, came to the conclusion that the basic depots of mercury were in the bones, liver, spleen, bone marrow, intestines and kidneys. The author writes that mercury periodically leaves these depots, enters the bloodstream, disperses throughout the body and causes the onset of poisoning.

R. Sussman (From an article of N. D. Rozenbaum, Gigiyena truda, 1923, 5-6) after rubbing mercury into the back skin of cats, observed the largest quantity of mercury in the kidneys, liver and large intestine. A. I. Cherkes (1957) noted that upon rubbing mercury into the skin, the largest quantity of it, excluding the annotated site, was discovered in the kidneys.

G. L. Sklyanskaya-Vasilyevskaya (1938) obtained interesting data on the effect of various conditions under which mercury poisoning occurs, such as its deposition in the body, and its distribution in the separate organs. The determining factor in this case is prolonged action. Thus, in animals suffering from the effects of metallic mercury vapor for ten days, 78% of all mercury retained in the body was observed in the excretory organs and only 22% in other organs. In animals inoculated with mercury for a longer time (20 days), the excretory organs contained only 52% mercury. Artificial decrease in diuresis causes a great accumulation of mercury in the body. Maximal quantities of mercury occur in the kidneys, intestines, heart and brain, that is, in all organs which manifest clinical contamination. According to the author, mercury, precipitating in the organs, does not lose its activity after deposition.

Material obtained by G. L. Sklyanskaya-Vasilyevskaya, as well as earlier published experimental observations of P. Ye. Syrkina (1934) confirm that the deposition of mercury in the body can occur with a change in state: upon the presence of large quantities of mercury in the kidneys indicate comparatively small quantities in the brain and vice versa.

Special note should be made of the fact that mercury can leave its depot and enter the blood over a prolonged period many years after cessation of all contact with it. It can cause depression in the general functional state of the body under the effect of harmful factors.

In conclusion let us comment briefly on certain data on the relative accumulation and dispersion of mercury under the effects of its compounds.

According to the data of M. F. Mirochnik (1934), various researchers studying mercury chloride poisoning observed the following amounts of it in various organs: kidneys, 0.002-0.014 mg; liver, 0.002-0.004 mg; large intestine, 0.002-0.003 mg per 100 grams. In other organs (spleen, thyroid gland, muscles, small intestine less than 0.002 mg mercury was observed, and only trace amounts were found in cells of the CNS.

In most studies mercury was not observed in saliva indicating that organomercury compounds, as distinct from inorganic mercury, is not distributed throughout the mouth. A significant quantity of mercury is found in the urine (0.48 - 0.74 mg in the daily voidance) and feces (to 0.245 - 6 mg/day). A definite correlation between mercury level in urine, feces, other biological substrates and length of exposure to organomercury compounds was not noted (S. I. Ashbel', V. A. Tret'yakova, 1957, 1958).

Prolonged circulation of mercury was observed when it was introduced as mercury salicylate (M. Ye. Zotova, 1944). About eight hours after intravenous injection of rabbits with ethylmercuric dicyandiamide, most of the mercury was found in the liver, then in the kidneys and the brain; after 44 days, most was in the brain, less in the liver and 4% most none in the kidneys (A. Swenson, 1959).

In the course of investigating the metabolism of this compound and of mercuric chloride, the radio isotope method established that organic derivatives of
mercury are more highly bound in animal organs than its inorganic salts: 10 times more mercury was found in brains, adrenals, medulla and spleens of rabbits poisoned by methylenamyercubic-dicyanodidane than in animals which had been given mercuric chloride (L. Frieberg, 1956).

Still earlier, in studies on the build-up and distribution of mercury, ethylmercuric phosphate and ethylmercuric chloride in the body, we came to the analogous conclusion as to the stronger adsorption of organomercury compounds not only in relation to their inorganic derivation, but with respect to vapors of metallic mercury (I.M. Trakhtenberg, 1951). The amount of mercury in the brain and spinal cord of animals in poisonings by vapors of organic mercury compounds increases, by our data, to 22-30 times its concentration in the brains of animals poisoned by vapors of metallic mercury. Upon a single administration of organomercury compounds via the digestive tract mercury appears in the brain and medulla of animals in quantities nine to ten times those appearing after the administration of mercury chloride. According to data of N. S. Pravdin and S. N. Kremneva (1939), the mercury content in brains of rabbits poisoned by ethyl-mercuric phosphate was much higher than in animals poisoned by mercury chloride.

Excretion of Mercury from the Body

Mercury is excreted from the body by glands of the digestive and intestinal tract, the salivary glands, kidneys, mammary and sweat glands. Excretion begins within several hours after poisoning, and even after a single dose of mercury, often continues for several weeks. After repeated doses, the elimination of mercury often takes even longer. N. P. Kravkov (1933) stressed that excretion of mercury is accomplished extremely slowly, sometimes requiring several months.

R. N. Vol'fovskaia (1928), A. M. Gel'fand (1928), I. G. Gel'man (1935) observed prolonged excretion of mercury from workers who had frequent contact with mercury and its compounds. Z. I. Khheyfets (1941) reported that, in cases of poisoning by high concentrations of mercury it appeared in the urine the first day of poisoning, while two patients, after thirty-five days excreted even more mercury than at the start.

L. Oberlander (1889) found mercury in the urine six months after undergoing a course of therapy with mercury compounds.

E. D. Storlazzi and H. B. Elkins (1941) after studying persons who used preparations containing mercury, noted that it was observed in the urine of some patients several months after the use of mercury was stopped.

N. P. Kravkov (1933) states that the largest quantity of mercury leaves the body via the feces; it is excreted in lesser quantities with urine; with sweat and then only trace amounts of mercury are left. Of the excretion of mercury by the sweat glands, this fact is established: in persons undergoing mercury therapy, gold objects (particularly rings) darken, covered with an amalgam of mercury. N. V. Lazarev (1938) stated that mercury, as with lead, manganese, nickel and certain other metals, are eliminated through the intestines in larger quantities than by the kidneys. He noted that mercury is excreted first by the digestive tract, which then ceases to have great significance in freeing the body from poisons. This knowledge is important in explaining certain symptoms of poisoning.

According to I. G. Gel'a'nan (1929), the elimination of mercury through the oral cavity causes the development of a specific stomatitis. He considers that mercury exits from the body primarily through the intestine, in a lesser degree through the kidneys. N. D. Rosenbaum (1934) proposed that most mercury is excreted via the kidneys. This view is also held by A. N. Oel'fand (1928). He stresses that mercury is eliminated by all organs but "the primary excretory route for mercury is the urine."

P. Ye. Syrkina (1930) in studying workers at a mercury plant established that, in the urine, mercury is observed in larger quantities than in the feces. According to the author, this indicates that mercury enters the workers' bodies primarily through the respiratory tract.
M. F. Mirochnik (1934) stated that up to 40% of all mercury eliminated from the body was excreted by the kidneys; in second place were the glands of the large intestine, in the third, the salivary glands.

N. I. Livshits (1955) in studying the excretion of mercury via urine and feces in persons with chronic mercury poisoning, came to the conclusion that significantly less mercury is excreted in the feces than in urine.

F. Koelsch (1959) considers that mercury is excreted from the body primarily by the kidneys.

F. Flyuri and F. Chernik (1938) suggested that mercury absorbed upon inhalation is excreted with the urine and feces almost as a unit quantity.

It is not hard to note that, in speaking of mercury's routes of entry, most researchers, as a rule, have not resolved the problem of the form in which mercury, in each specific case, interacts with the body. One can postulate that, depending on this, mercury can react as inorganic salts, organic compounds or as metallic mercury vapor, that it is eliminated from the body primarily through the intestines or the kidneys.

A. I. Cherkes (1943) considers that greater or lesser participation of one or another organ in the elimination of the poison depends primarily on the physical and chemical properties of the poison.

A. Kuznetsov (1934) stressed that the state in which mercury enters the body and its method of administration are decisive in determining its route of excretion. The author noted that, upon penetration of the skin by mercury, (primarily through the rubbing in of ointments containing mercury) most mercury is eliminated with the feces, the remainder with urine. Upon the intramuscular injection of a mercury-containing solution, the bulk of the mercury is excreted via the kidneys; upon intravenous introduction of mercury, the metal is eliminated in both urine and feces as a unit quantity.

Mercury is excreted by the liver to a greater or lesser degree. In the opinion of B. Ya. Agronovich (1948), this explains one of the phenomena of its hepatotoxic effect.

In analyzing for the presence of mercury in the duodenal contents in chronic poisoning cases, O. Ya. Mogilevskaya (1947) concluded that excretion of mercury from the liver with the bile had definite practical significance. Nevertheless the author believes that the significance of the bile in mercury excretion is limited by the fact that mercury evidently reprecipitates in the intestinal wall, in the blood stream and reenters the liver by the hepatic portal vein. The data of O. Ya. Mogilevskaya indicates that, in chronic mercury vapor poisoning, mercury is excreted from the liver with the bile in quantities approaching those excreted in the urine.

There is special interest in the problem of mercury excretion via the mammary glands. M. F. Mirochnik (1934), in surveying literature data, says some authors reject the possibility of the elimination of mercury by the mammary glands. At the same time others noted definite and continuous excretion. N. V. Lazarev (1938) noted that mercury, like lead, can be excreted in the milk and stressed that: "We don’t know on what scale these poisons are eliminated in the milk of nursing women.

Cases of mercury poisoning in the newborn are known if the nurslings ingest mercury compounds. The literature described such a case in which completely healthy persons drank milk from cows which had been rubbed with a mercury ointment. The people showed signs of intoxication (stomatitis, stomach pains, diarrhea).

Some investigators detected traces of mercury in the milk of mothers receiving a course of treatments with mercury preparations and also in women with mercury poisoning symptoms. E. I. Kheyfets (1941) described a case of mercury vapor
poisoning in a family of four. Mercury was found in the milk of a nursing mother (0.004 mg/100 ml milk). Significantly, she continued to excrete mercury with the milk for quite a long time after poisoning.

There is also literature data referring to experiments in which, upon the inhalation of mercury vapor, mercury is excreted not only by the kidneys and intestines, but also through the lungs (C. L. Sklyanska-Vasilevskaya, 1938; A. Stock and W. Zimmerman, 1929).

In explaining a contrasting point of view excluding the possibility of mercury excretion from the body with exhaled air, Gerstner reported on his experiment in which he did not find mercury in air exhaled by persons who earlier had inhaled mercury vapor and then had spent time at sites with pure air.

There is still the question of establishing the practical value of mercury findings in experiments for the diagnosis of mercury poisoning. M. A. Frantsuzova (1940) believes that basic analyses for mercury must consider urinalysis results. I. C. Fridlyand (1963) also noted that practically the best data on urinary mercury content stressed the significance only of the comparatively large quantities of mercury observed.

A. M. Gel'fand (1928) considered urinalysis for mercury as an early method for diagnosing mercurialism, and that mercury excretion proceeded intermittently, first being absent and then present.

It is necessary to be reminded again that insignificant quantities of mercury can be detected in urine of persons who have never encountered mercury. Relatively high concentrations of mercury, as a rule, occur in persons who have had contact with mercury but all cases of these do not display symptoms of intoxication. A. Stock believes that mercury content in the daily urine of more than 0.01 mg indicates the possibility of poisoning and a content of over 0.05 mg usually leads to a confirmed diagnosis of mercurialism.

In agreement with the data of Totusek (cited in J. Teisinger, S. Scramovski, I. Srbova, 1959), the maximum safe limit of urinary mercury concentration is 0.2 mg/l. Especially high and little justified quantities (0.25 - 0.3 mg) of mercury were recommended as permissible urinary concentrations by the American investigator (L. Fairhall, 1949). This author cites the fact that this quantity of mercury in the urine corresponds with a permissible (by American standards) air concentration of (0.1 mg/m3).

It should be considered unfounded that such a direct quantification between urinary and air concentrations of mercury exists.

According to I. C. Fridlyand (1963) the occurrence of high concentration of mercury in excrete in the absence of some symptoms of intoxication does not truly diagnose poisoning; on the other hand the author admits the possibility of mercury poisoning in the absence of high urinary mercury concentration. Ye. Ye. Syroyechkovskiy (1933) stated that in cases where mercury appears in excreta, but clinical symptoms of intoxication are not evident, one can speak not of poisoning but of "carrier-ship" of mercury. Based on data from the investigation of 233 mercury production workers, I. G. Fridlyand concluded that even the presence of (0.1 - 0.4 mg/l) mercury in the urine does not always indicate poisoning.

P.Ye. Syrkina studied urine of animals poisoned by mercury vapor and came to an analogous conclusion that mercury in the urine corresponds to the mercury uptake phase which later can lead to clinical symptoms of poisoning.

I.D. Gadaskina (1939), in discussing the diagnosis of mercury poisoning, stated that in case mercury occurs in the excreta in the absence of some sign of poisoning "it is possible to think not only of having taken in poison but of poisoning such that the yet healthy man can still excrete mercury from his depots for a long time." The author stresses that, on the other hand, the absence of mercury in the urine still does not indicate that there is no poisoning, rather that the body is excreting no mercury at that time. This is
confirmed by materials obtained by S. S. Shalyt (1940) in the process of periodic surveys of workers in the mercury industry. According to these data, there are often cases of intoxication despite negative results of urinalysis for the presence of mercury. I. D. Gadaskina believes that the state of the organism cannot be judged by the presence of more or less mercury found in the excreta, because following a period of intoxication, it is not excreted continuously and therefore is no parallel to the development of intoxication. An analogous point of view is that of L.M. Frumin (1936) that "the presence of mercury in the urine does not move parallel to the gravity of poisoning." The results of the experiments of P. Ye. Syrkina (1934) and C. L. Sklyanskaya-Vasilyevskaya (1938) indicate that upon the inhalation of mercury vapor by animals at the beginning of poisoning, where symptoms of intoxication have not yet occurred, much more mercury is excreted than later. A. M. Gel'fand's data (1928) indicates that mercury first appears in the urine, then all the symptoms of mercury poisoning are developed in slight degree.

In evaluating several methods of treating mercury poisoning, E. I. Kheyfets (1940) stated that a complete parallelism between improvement in the condition of the patients and urinary mercury excretion did not occur, but in a majority of cases, at the end of therapy urinary mercury excretion had diminished.

According to data of A. Ye. Kul'kova (1931), in patients with mercurial encephalopathy, the urinary excretion of mercury occurred inversely to the severity of the illness. Other data published by I. N. Livshin (1939) noted the presence of a definite relationship between mercury excretion and the degree of intoxication.

H.A. Frantsuzova (1940) also stated that there exists a dependence between the quantity of mercury excreted in the urine and the appearance of clinical symptoms of intoxication. Along with a majority of other investigators, the other stresses that "there is no complete parallelism in this respect."

Toxic Doses and Concentrations

Data on what concentrations of mercury vapor can lead to chronic intoxication of humans under everyday conditions are contradictory.

A.N. L'vov (1939) stated, on the basis of many years of observation, that the effect over the course of a few years of mercury vapor concentrations on the order of (0.04 - 0.05 mg/m3) led to chronic poisoning in a definite number of cases. According to the author, the greatest number of chronic cases occurred at a mercury vapor concentration of 0.03 - 0.05 mg/m3. According to G. F. Gothlin (1911) daily inhalation of from 0.4 -- 1.0 mg Hg for a few months is sufficient to produce chronic poisoning. J. Turner (1924) noted the possibility of mercury poisoning arising from 3-5 hours daily exposure to mercury in 0.771 - 1.285 mg quantities. In his opinion, chronic intoxication can develop after contact with mercury in concentrations >0.02 mg/m3. According to data of L. Teleky (1925), daily inhalation of mercury in concentrations on the order of 0.04 - 0.1 mg/m3 over a few years leads to the development of severe chronic poisoning.

K. Lehmann (1919) stated that, during the eight hour working day, air containing an average of 0.15 mg/m3 mercury can produce chronic poisoning. I. Henderson and H. W. Haggard (1930) consider that mercury poisoning develops from daily three to five hour exposure to 0.7 mg/m3 for two to three months. The quantity of mercury ingested daily and causing chronic poisoning, according to: F. Flury's data (1938) is 1 mg; H. Fuhner (1927) - 0.1 mg (for highly sensitive persons) - 0.05 mg); P. Neal (1937) - 0.007 - 0.2 mg/m3 T. Rutherford, A. Johnstone (1942) - more that 0.025 mg/m3 A. Stock (1926) - 0.001 - 0.005 mg/m3.

The concentration of metallic mercury and doses of mercury salts producing acute poisoning, also producing chronic intoxication is not exactly determined. N. A. Vigdorchik (1940) states that acute poisoning can arise at concentrations of 1.5 mg/m3. According to O. I. Gla zova (1952) lethal intoxication developed upon the inhalation of 2.5 gm of mercury. O.Ya. Mogilevskaya (1947) observed the development of intoxication upon the presence of 5 mg/m3. The author described a
case of massive intoxication, when the mercury content of the air of a dormitory was 0.13 - 0.8 mg/m³.

Interesting data on toxic doses and concentrations have been obtained in experiments on mammals. A mercury concentration of 16 mg/m³ is lethal to guinea pigs after three day's exposure for two to four hours per day. The toxic concentration for guinea pigs is 0.2 - 0.5 mg/m³ under conditions of daily exposure for four to six hours. Animals continuously exposed to mercury vapor concentrations from 3.5 - 5 mg/m³ died within 115 - 150 hours after the beginning of the experiment. Upon periodic exposure to higher concentrations (up to 8 mg/m³) they died after 35 - 70 days. (Kh. Z. Lyubetskiy, 1953). The lethal concentration for dogs in 20 - 50 mg/m³, after daily eight hour exposures (the animals died within one to three days) and, at 12.5 mg/m³, the animals died after six to sixteen days. At a 3 - 6 mg/m³ dose, the typical picture of mercury poisoning appeared; at 1.9 mg/m³, no visible signs of intoxication appeared after forty days. (A. Fraser, K. Melville, R. Stekie 1934). Mercury vapor concentrations on the order of 0.015 - 0.1 mg/m³; 0.035 - 0.04 mg/m³ (N.M. Gimadeyev, 1958); 0.02 - 0.05 mg/m³ 0.008 - 0.01 mg/m³ 0.005 - 0.02 mg/m³ (V.N. Kurnosov, 1962) produced in experimental animals (rabbits, cats, white mice) reversible changes in conditioned reflex activity. Other changes of a functional nature were noted at these concentrations. The heterogeneous mercury sensitivity of various animals was established in the course of experiments. White mice, rats and rabbits were most sensitive and guinea pigs less so.

The lethal dose of soluble mercury salts upon ingestion by animals is 0.2 - 0.3 gm (M. D. Shvaykova, 1959). Upon intravenous introduction this dose is two times smaller. H. S. Znamenskiy (1949), N. D. Tushinskiy (1939) and other investigators established that the lethal dose was between 0.1 - 0.5 gm. O. I. Clazova's data (1952) indicates that 0.1 - 0.2 gm of mercuric chloride is toxic and a 0.5 gm dose lethal when taken internally. Mercury nitrate is acutely toxic at higher doses. Acute poisoning by mercury monochloride is possible upon intake of 2 - 3 gm.

Concentrations and doses of mercury, producing experimental poisoning in mammals follow: minimal lethal dose of mercury chloride upon introduction into the stomachs of white mice is 0.55 - 0.6 mg/kg (L. U. Medved', 1944). Upon administration by this route to rabbits the lethal dose was 12 mg/kg by the 27 - 32nd day from the moment of introduction, while 15 mg/kg - by the 15 - 16th day; 20 - 25 mg/kg - by 4 -11th day, 40 mg/kg in 1 day (P. T. Karavayev, 1939; N. S. Pravdin and S.N. Krenneva, 1939; our data, 1950). The toxic dose of mercury chloride for rabbits was (subcutaneously) 1 - 20 mg/kg, at which intoxication appeared 50 - 90 days from the beginning of the experiment (V. A. Shalimov, 1956); upon introduction into the stomach -- 1 - 8 mg/kg (I.N.Trakhtenberg, 1959).

**BASIC INDUSTRIAL PRODUCTION, PROCESSES AND OPERATIONS, CONNECTED WITH POTENTIAL DANGER OF MERCURY INTOXICATION**

Of the branches of industry where mercury and its compounds presently play a role in the production of poisons, the most important are ore refining, metallurgical, chemical, instrument building, electro-vacuum and pharmaceutical.

With mercury and its inorganic compounds, as noted above, one can include its multitudinous derivatives originated by scientific research and academic laboratories, the bureau of standards, instrumental control and calibration services, boards of weights and measures, and establishments for medical and biological profiles.

Below appears a list of specific products typical of cases of use and processes connected with danger from the harmful action of mercury. It includes the extraction of metallic mercury and its ores and also the smelting of mercury from ore; various amalgamation methods, especially for obtaining noble metals from ores, alloys and scrap metal; teeming; filtration, purification and transportation or metallic mercury; production and use of measuring instruments; mercury thermometers, barometers, areometers, manometers, monovacimeters, etc.; production and use of electronic devices; AC rectifiers, mercury contacts;
mercury toluol thermoregulators, mercury shunt circuits, calomel electrodes and others; the employment of mercury rectifying devices in power transmission lines; the production and use of vacuum diffusion pumps and special mercury vacuum installations; the production of incandescent bulbs, quartz and luminescent bulbs, x-ray tubes, radio tubes; preparation of various amalgams; manufacture and use of corrosive sublimate, calomel, mercuric oxide, mercury salicylate, ethylmercuric chloride, phenylmercuric acetates, mercury cyanide, and other inorganic and organic mercury derivatives; the manufacture and use of explosives incorporating mercury fulminate; heat gliding and silvering processes (coating metal objects with gold and silver amalgams with subsequent heating to remove the mercury); the use of mercury in electrolytic processes as a cathode (usually in chlorine production); use as electrolytic alkali, the production of viscose fiber by a mercury method; the use of mercury as a catalyst in various chemical processes, principally, in the production of acetic acid, pro-medol and streptomycin; preserving of wooden structures such as piles and columns, with organic (ethylmercuric phosphate) and inorganic mercury solutions; use of these same solutions in disinfecting wood, purifying reservoirs and other small enclosed volumes, in which mercury had been detected earlier; work with blueprint masters using mercury lamps; the use of copper and silver amalgams in tooth fillings; use of mercury dichloride as a disinfectant, the use of metallic mercury in academic laboratory experiments and demonstrations.

I. G. Fridlyand (1957), in analyzing results of periodic medical examinations of those working with mercury and its compounds, concluded that exceptional hazards, from the standpoint of labor conditions, occur in the manufacture of mercury fulminate, organomercury pharmaceuticals, thermometers, and also in the extraction and smelting of mercury.

The hazard of acute mercury intoxication can arise upon the shattering of mercury bulbs, upon the burning of so-called "Pharaohs' serpents, separation from mercury thiocyanide, upon the explosion of mercury fulminate enclosed in sites, in the welding and repair of boilers containing mercury, in work with mercury disinfectants (F. Flury and F. Zernik, 1928).

E. Starkenstein, E. Rost, S. Pol (1931) strongly emphasized that occupational mercury poisoning can occur wherever mercury is handled. They, along with F. Flury and F. Zernik fully understand the possibility of poisoning through the use of mercury disinfectants.

L. Teleky and I. Kober (1925) in a special study linking the characteristic processes connected with mercury poisoning hazards, enumerated the following industries which, in their opinion, were the most important from a hygienic point of view: ore extraction, smelting, manufacture of various measuring devices, extraction of gold and silver, manufacture of electrodes, electric batteries, etc., synthesis of mercury-containing chemicals, mirror production and various steps of felt and felt hat making.

The literature records cases in which mercury vapor poisoning has occurred as the result of vaporization from storage sites, drying and especially through washing. V. K. Navrotskiy (1928) described a case of mercurialism in a launderer scrubbing the clothes of workers who had contact with mercury. V. A. P’yankov’s research permits the possibility of mercury vapor poisoning by "desorption" from specialized clothing during storage or drying in closed containers.

If at the end of the last century Layet (1887) had noted 24, a few years later L. Teleky (1912) noted 29 kinds of industries in which mercury poisoning could occur, then by the end of the thirties, according to P. Neal (1938) the number had risen to 40.

According to our data, there are now over 160 types of industry, processes and operations in which it is possible to encounter mercury in the air under working conditions.

In most such cases poisoning occurred when workers had continued long term contact with mercury. If we note that in many cases there are intermittent
instances of contact during various persons' professional activities, then it is obvious that the number affected is significantly higher.

In connection with the broad distribution of mercury there are many uses necessary to scientific and technical activities and processes in which man can contact mercury. This makes necessary a multitude of continuous measures and practices of a preventive and hygienic nature.

Data presented below characterizes labor conditions determining the possible hazards of production processes at establishments, such as metallurgical plants, in which mercury is obtained by a pyrometallurgical method.

Extraction of Cinnabar and Production of Mercury

The most hazardous working conditions determining the possibility of significant air contamination by mercury prevail at premises of metallurgical factories during the extraction of mercury from ores by the pyrometallurgical method.

V.K. Navrotsky (1928), after studying working conditions at one such plant, reported that during recovery of mercury from cinnabar 1 - 32 mg/m3 Hg was detected in the surrounding atmosphere. The author believes that a uniquely effective corrective measure in combatting occupational mercurialism at mercury plants is the full mechanization of production and adequate ventilation of the site.

E. V. Selivanov (1926) investigated labor conditions of all mercury and cinnabar extraction industries and found in the air of such premises 1.5 - 14 mg/m3 Hg. According to the author's data, at the Nikitovsk mercury factory in 1926 the concentration of mercury vapor in the air in the course of operations reached a quantity a hundred times the permissible level. Presently at this facility working conditions have improved significantly; several shops have been rebuilt and equipment installations are effectively ventilated. The aerial mercury concentration of industrial premises decreased significantly as shown by the studies of our colleague G. I. Kulik (1961). The aerial mercury vapor concentrations at many work sites still exceed permissible levels. Analogous data were obtained by I. L. Kurinniy (1964) and N.I. Petrova (1966).

In the extraction of mercury even under mechanized labor conditions there still remain certain operations exceptionally dangerous with respect to the possible effects of mercury. These include, principally, the blending and grinding of mortars, cleaning of condensates. Additionally, the possibility is not excluded that the completion of short term emergency jobs (continuous lining of furnaces, discharge of cinders from hoppers, furnaces, etc.) connected with the possible penetration of the respiratory zone of workers of high concentrations of mercury occurs.

The most complete study of working conditions in the pyrometallurgical extraction of mercury was investigated by N. I. Petrova (1963, 1964, 1966). In analyzing working conditions at the Nikitovsk Mercury Combine, the author convincingly indicated the role of technological (improvement of equipment) and hygienic measures in decreasing the aerial mercury content. Thus, the primary sanitary significance of the furnace boiling layer compared with furnace pipes, etc. was shown. The decrease in mercury concentration in the air led to changes in the clinical picture of the effect of mercury on the organism. Most materials on the results of periodic medical surveys and data on the dynamic observations of the state of health of workers showed that presently the attention of medical personnel should be concentrated on the initial symptoms of mercury intoxication.

Of special note are the discoveries of N.I. Petrova and the first descriptions in the hygienic literature of mercury vapor contamination at mercury mines. The presence of mercury vapors at the shaft head was described by M. A. Kulbasov (1954) who established that the mercury vapor content varied between 0.015 - 0.34 mg/m3. Such an analysis was made in 1960 by scientists at the Thilisi Scientific Research Institute of Industrial Hygiene VTSCPS. Their data showed that there was aerial mercury vapor at underground workings after the arrival of
workers (within two hours after the explosion of mercury fulminate
electrodetonators and that mercury concentration still exceeded permissible
levels. V. L. Kvarikhava (1963) observed mercury vapor in the air of the
Kvarchel coal mine.

G. Sh. Gabunaya (1961) commented on the presence of mercury vapor at the
Chiatursk manganese deposit. He noted that mercury vapor exceeded permissible
levels two to three times and were detectable in the air two to three hours
after explosions. Simultaneously an increased mercury content in the urine of
shaft workers was observed.

In contrast to the cases above where the sources of mercury vapors were mercury
fulminate detonators, N. I. Petrova established that the source of mercury vapor
in the air of mercury ore deposits was a mixture of volatile mercury compounds
contained in the ore. In connection with
this, prolonged contact with ore bodies leads to continuous contact with mercury
vapor in concentrations exceeding permitted levels. In some persons symptoms of
chronic mercury effects (gingivitis, bleeding gums, excretion of large amounts
of mercury in the urine) were detected.

Instrument Building

In instrument building establishments there are many processes connected with
the storage, transportation, purification, and filtration of metallic mercury
and also the drawing of the latter into capillary tubes. The latter has
parallels with similar operations in the production of industrial, chemical and
medical thermometers, areometers, thermoareometers, and other measuring devices
which occupy a comparatively small contingent of workers, engineering, and
technical personnel.

In connection with this, up to 1917 most measuring devices were imported into
Russia from abroad, domestic production of these was limited to a few
specialized shops, employing few workers, in Moscow, Kharkov and other cities.

Currently the manufacture of various measuring devices is a large scale industry
in the USSR. Naturally there is an increased personnel contingent employed in
instrument building factories. In speaking of processes and operations connected
with the manufacture of mercury thermometers one can state that this consists of
two stages. The first --making of the glass parts and filling them with mercury;
the second --calibrating them. From the hygienic point of view, the riskiest
operation is calibration which, until the present, has been done by the most
primitive method. This calibration process involves several operations with
exposed mercury in which its vapors escape into and contaminate the air of the
industrial premises. Under modern industrial conditions for the production of
mercury thermometers, manipulation of exposed mercury is confined to the
following basic operations: the filling of the ampule with mercury, decanting
excess mercury, measuring the scale, unsoldering the capillary, and a cycle of
graduating operations, and applying the scale to the thermometers. After these
operations comes the testing of the completed thermometers after which they are
stored. Production control is carried out according to state standards for
various types of thermometers.

Thus, mercury can be released in the work zone not only during calibration of
thermometers, but at all subsequent stages of the technological process. The
degree of contamination of the industrial premises depends significantly on the
completion of the various operations with cold or hot mercury. The most
conclusive study from the hygienic view is one of labor characteristics in the
course of mercury thermometer production established by A.N. L'vov (1939) as
comparative tables. The

Obsolete and hazardous forms of mercury instrument production, from the hygienic
point of view, frequently include the non-mechanized filling of tubes with
mercury and is not encountered in highly specialized plants. However, in small
scale production, primarily in shops of the KIP, where such instruments are
sometimes made, this is encountered somewhat rarely. In these shops work with
hot mercury is not kept to a minimum; premises in which mercury is handled are
not isolated from other buildings; instruments filled with mercury are taken to other (non-mercury) locations as a consequence of which mercury from these instruments can contaminate “clean” sites. Vacuum methods are slowly being introduced for filling thermometers. Suitable attention should be given to the location and environment of instrument building plants (according to volume and production scale).

Electrovacuum Production

Mercury is widely used in the manufacture of various electro-vacuum devices and instruments, particularly electric lights, among them the widely used luminescent lamps, gas filled argon-mercury lamps (IGAP), mercury vapor quartz lamps (PRK), erythemic and bactericidal lamps, and cold cathode neon lights. Mercury content in these devices varies (depending on the intended use of each). Thus in DAR tubes the amount of mercury is 40 – 90 mg., in luminescent lamps, from 40 – 350 mg., and in SVDSh and PRK lamps, from 250 – 560 mg.

Continuous increase in the production of mercury rectifiers, ingitrons and gasotrons occurs. The mercury content in these reaches significant quantities (from 10 gm to a few kilograms).

The production of electrovacuum devices is characterized by the possible effect on personnel involved of a chemical and physical hazard complex, among which mercury plays an important role.

The fullest treatment of industrial hygiene in the mercury rectifier industry is in the works of E.I. Gol'dman (1956, 1959, 1960, 1964). Some important questions have been treated in the works of A.S. Shafranova (1924), K. A. Reynberg and Ye. N. Kuprin (1926), K. A. Nikonova, V. N. Grun' (1960), M. P. Bobrova and coauthors (1960) and others.

The possibility of harmful mercury effects in electrovacuum premises first arises in preliminary production, particularly the process of tantalum sintering at 1500°C in vacuum formed by mercury vacuum pumps.

Even more important is the possibility of air contamination by mercury from assembly production. The latter is connected with the generation of high vacuums necessary for the further effective exploitation of the instrument, reached at the present by mercury pumps within which mercury is simultaneously accumulated and heated to a high temperature. A. V. Dmitriyev (1927) in studying electric bulb production found mercury in the air in concentrations of 9.4 – 15.5 mg/m3. In these places mercury is not only found in the shop itself but at significant distances and in adjoining buildings. The author concludes that there is a genuine hazard in the production of vacuum products using mercury.

Additionally, many vacuum treatment processes employ mercury. In one type of device (rectifiers, mercury-quartz lamps), mercury is removed before evacuation and in another (luminescent bulbs, etc.) after the object is heated in a vacuum.

Disregarding the harmless individual operations involved in introducing mercury into a device, there are steps in the assembly process involving the purification of mercury, utilization of scrap, and also the tendency of glass parts to shatter. One can see the real danger of air contamination at premises where vacuum devices are assembled. This is confirmed by data of E. I. Gol'dman (1964) that there is air contamination by mercury vapor in 0.01 – 0.03 mg/m3 concentrations both in manual and mechanized evacuation.

In mercury instrument production all processes (measuring mercury into heated devices, sealing, etc.) begin with evacuation accompanied by the evolution of mercury vapor.

In the vacuum treatment of mercury-quartz devices (PRK lamps, SVDSh) filling and emptying the device and also the measuring of mercury is done with the air of a powerful gas heater which can contaminate the air significantly.

The source of contamination can be both in the mounting of bases and the installation of new lamps, when simultaneously with the evolution of mercury
vapor from the surface field, the equipment can be contaminated by mercury droplets falling from the head.

Mercury vapor enters the air from broken mercury-filled devices in quantities which can make up 0.5% of their gross output; penetrating the air of the work zone are evolved gases from mercury vapor and oil vapor pumps; the evaporation of mercury from open surfaces of mercury measuring devices, which attain the high temperature of the surrounding air.

Mercury vapor in the air settles on surfaces of equipment and installations, sorbs onto construction material, making up a significant air contamination source. Analysis of smears shows mercury can be taken from walls and equipment (0.006 - 0.03 mg/m³), surfaces of luminescent bulbs (up to 0.004 mg), and skin of hands 0.002 - 0.4 mg.

At the time of periodic medical check-ups some persons showed symptoms of mercury effects (headaches typical of mercurialism, increased excretion of mercury with the urine).

Prophylactic measures in the electrovacuum industry consist of isolation of persons who work with mercury and mercury thermometers and mercuryless pumps, the protection of structures with mercury-impermeable substances; correct storage of mercury reserves; lowering the air temperature; and cooling of dispensing devices and evacuation equipment; sensible construction of storage tanks; improvements in general and local ventilation (especially placing of evacuation apparatus under exhaust hoods); conscientious removal of liquid mercury droplets and regular cleaning of shops with demercurizing chemicals.

### Table 7

<table>
<thead>
<tr>
<th>Name of Operation</th>
<th>With hot mercury, linked with the presence in the air of significant quantities of mercury vapor</th>
<th>With open mercury at room temperature</th>
<th>With enclosed mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling of thermometers with twice and thrice distilled mercury (hand operation)</td>
<td>Determination of the thermometer's reservoir size</td>
<td>Graduating thermometers</td>
<td></td>
</tr>
<tr>
<td>Filling of thermometers in a press vacuum apparatus or a high vacuum apparatus (machine operation)</td>
<td>Determination of the capillary canal size</td>
<td>Engraving thermometers</td>
<td></td>
</tr>
<tr>
<td>Experimental studies of thermometer filling</td>
<td>Closing thermometer</td>
<td>Waxing thermometers</td>
<td></td>
</tr>
<tr>
<td>Chemical purification of alkali, nitric acid and water solutions</td>
<td>Removing the mercury from defective thermometers</td>
<td>Technical control and testing of thermometers</td>
<td></td>
</tr>
<tr>
<td>Electrolytic purification of mercury from contaminating metals</td>
<td>Storage and transport of broken thermometers and mercury</td>
<td>Storage and transport of finished thermometers</td>
<td></td>
</tr>
<tr>
<td>Distillation of mercury</td>
<td>Pouring mercury from bulbs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finishing of thermometers (digital and cylindrical) in which a heated thermometer is opened for the addition or subtraction of a quantity of mercury in the capillary</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mercury vapor enters the air from broken mercury-filled devices in quantities which can make up 0.5% of their gross output; penetrating the air of the work zone are evolved gases from mercury vapor and oil vapor pumps; the evaporation of mercury from open surfaces of mercury measuring devices, which attain the high temperature of the surrounding air.

Mercury vapor in the air settles on surfaces of equipment and installations, sorbs onto construction material, making up a significant air contamination source. Analysis of smears shows mercury can be taken from walls and equipment (0.006 - 0.03 mg/m³), surfaces of luminescent bulbs (up to 0.004 mg), and skin of hands 0.002 - 0.4 mg.

At the time of periodic medical check-ups some persons showed symptoms of mercury effects (headaches typical of mercurialism, increased excretion of mercury with the urine).

Prophylactic measures in the electrovacuum industry consist of isolation of persons who work with mercury and mercury thermometers and mercuryless pumps, the protection of structures with mercury-impermeable substances; correct storage of mercury reserves; lowering the air temperature; and cooling of dispensing devices and evacuation equipment; sensible construction of storage tanks; improvements in general and local ventilation (especially placing of evacuation apparatus under exhaust hoods); conscientious removal of liquid mercury droplets and regular cleaning of shops with demercurizing chemicals.
Mercury Pharmaceutical Production

A number of studies exist on the industrial hygiene of plants producing mercury-containing medicinal preparations and also the production of individual packets for the saturation of bandages. V. A. Lebedev (1945) stressed strongly that "for the industrial physician mercuric chloride is important not only for itself but because during work with it, mercury vapor contaminates the air". A study of working conditions at one of these plants showed that in the preparation of these individual packets the air was contaminated and the following Hg concentrations were recorded: in the HgCl₂ shop, 0.02 - 0.06 mg/m³, in the cutters, 0.06 - 0.08 mg/m³, in the insertion room, 0.02 - 0.03 mg/m³ and in sterilization, 0.02 - 0.05 mg/m³.

Mercury vapor was also detected in storage areas (0.02 mg/m³) and in a dressing room washed with HgCl₂ (0.04 mg/m³). The temperature in various parts of the facility varied between 21 - 30°C with a relative humidity between 60 - 80%.

As a result of these studies corrective measures were undertaken leading to significant improvements. The danger of mercurialism decreased from beginning to end of the bandage production process, not only reducing the number of persons having contact with mercury but significantly shortening the period of contact. The corrosive sublimate department was also isolated.

Analogous data were obtained by G. L. Sklyanskaya-Vasilevskaya (1938) who investigated labor conditions in a factory making individual packets. The original production methods released metallic mercury and corrosive sublimate vapor into the air and significant concentrations of mercury vapor (0.07 - 50 mg/m³) and HgCl₂ (0.005 - 0.02 mg/m³ were found.

Study and analysis of production processes showed that contamination of the working premises occurred during sterilization of the packets in an autoclave. Close observation at the time revealed the accumulation of metallic mercury. Under sterilization conditions "the dispersion of corrosive sublimate occurs under the influence of many factors leading to one outcome". Thus hydrocarbons added to the HgCl₂ to facilitate dissolution forced the evolution of metallic mercury upon heating. Simultaneously experiments confirmed that the addition of iodine decreases this problem ten times. In the opinion of G.L. Sklyanskaya-Vasilyevskaya (1938), the usual method dissolving HgCl₂ in factories must change. Corrective measures must be carried out in such facilities, the technical process should be both changed and sealed off.

Working conditions in such factories were well studied by V. A. Pokhvalenskiy (1929). A pharmaceutical factory which he investigated produced calomel, corrosive sublimate, white mercury precipitate, mercuric oxide, mercuric iodide, mercury benzoate, mercury nitrate, mercury cyanide and other medicinals containing mercury, corrosive sublimate tablets and mercury ointments. The author in describing the technological processes for the indicated preparations noted that the concentration of mercury in such production premises varied between 1 - 40 mg/m³ and significantly exceed the maximum permissible concentrations established for mercury vapor. In all departments there was a high level of mercury dust contamination of the air, especially in the loading and unloading of calomel mixtures and in the discharge of corrosive sublimate. The author believes that the various sanitary and health improvement procedures in industry should be general. They include the provision of the premises with adequate exhaust ventilation, the sealing off of processes and operations, the periodic rotation of workers to remove some of them from contact with mercury and individual prophylactic measures.

Problems of improving working conditions in chemical and pharmaceutical industries using mercury or its compounds were addressed in works of G. D. Ul'yanova (1956), I. F. Nikonets, Ye. Ya. Tsil'man, M.I. Livshits (1959). Significant air contamination with mercury vapor is connected with imperfect technological processes -- the presence of exposed mercury, insufficient sealing of installations and equipment, the large number of mercury operations and the absence of continuous production, etc.
I.F. Nikonets (1959) detected mercury in all air samples taken from floors, walls, equipment, workers' hands at sites engaged in the production of creams containing mercury salts (mercury amidochloride). The source of contamination is vaporization from exposed surfaces during the packing of mercury in containers, mixing it with oil, heating and cooling of creams in open vats, crystallization, mechanical treatment and packing of creams. The author suggests as a health measure, a replacement for mercury amidochloride in cream production, the isolation of all mercury operations, the improvement of process technology, and the improvement of general and local ventilation.

In the chemical and pharmaceutical industry metallic mercury is used as a catalyst (M. Z. Gofman, 1963) which accounts for its place in the current literature. It has been shown that the use of mercury as a catalyst in promidol synthesis leads to air and equipment contamination with mercury which, at the high temperatures of technological processes and also in later use, dictates its removal from the air as a potential toxic substance.

In the hygienic evaluation of streptomycin production we established the contamination of air with mercury as a consequence of the production use of mercury chloride as a catalyst for aluminum iso-propylate synthesis. The data presented indicate that the use of even small quantities of mercury catalysts can contaminate work zones in quantities exceeding permissible limits.

Of interest in this respect is material published by the Leningrad Institute for the Organization of Economics and Labor Protection which contains not only detailed accounts of the sanitary aspects of the various "mercury occupations" but the "outline of basic safety principles in these occupations" (N. A. Vigdorchik, 1934). Studies of labor conditions in working with metallic mercury by the personnel of the institute included the isolation of pure mercury (production of mercury vessels, small rectifiers, thermometers and large rectifiers). G. S. Erenberg and M. Ye. Slanskaya (1934) noted that "these four aspects of working with metallic mercury are typical of problems besetting the industry and that studies of working conditions in the indicated industries are the basis for conclusions about various aspects of mercury operations".

As a result of this study the aerial mercury content was found to be 0.012 - 0.2 mg/m³ for a variety of reasons.

It is known that apparatus and installations used in production are often made of glass and break easily spilling mercury onto the shop floor.

In many devices and apparatus the mercury surface is exposed. Additionally, a significant quantity of mercury is found on the floors, tables and equipment.

In the production process there are a series of operations in which mercury is heated which leads to high air temperatures in the working environment.

Many operations connected with the heating of mercury contaminate the hands of workers engaged in them and mercury can also enter the air in this way.

A goal of the investigation was the improvement of health and working conditions in mercury shops: full isolation and ventilation improvements in mercury shops and their isolation from nonmercury operations; use of special equipment and devices in handling mercury-containing equipment to prevent mercury vapor output; cleaning of glass and other equipment which had contained mercury by a pneumatic method.

In recent years the attention of hygienists has centered on the contamination of air around mercury plants (V. N. Kurnosov, 1961, 1962; V.P. Melekhina, 1959) established the role of secondary entry of mercury into the air of the work zone (M. N. Korshum, 1969) and the distribution of "mercury objects" in urban conditions (I. M. Trakhtenberg, 1964).
CHAPTER IV

MERCURY IN MODERN URBAN CONDITIONS

The presence of branching networks of urban electrified transport, many establishments, shops and departments of the manufacturing control and measuring instruments, mercury-filled instrument adjustment services, the bureau of control and measuring apparatus, repair shops for mercury instruments, departments of weights and measures, glassblowing shops, etc. and also construction of new and exploitation of old active city electrical generating stations with functioning "mercury contacts", a wide span of laboratory work, the growth and distribution of equipment fittings containing mercury, medical and biological profile institutions all confirm that today mercury is universally significant as a most important toxic substance. Note that the aerial mercury content in work zones of industrial establishments usually is on the order of hundredths of a milligram per cubic meter. If in the 40's and 50's the aerial mercury content at production facilities fell and was close to 0.01 mg/m³, then later such a decrease from the permissible concentrations was noted more often. In most current cases of aerial mercury vapor at industrial establishments, concentrations detected are very low, less than 0.01 mg/m³. This has long represented a unit quantity.

As an example, consider the aerial mercury content dynamics of several "mercury objects" in Kiev from 1948 - 1958/62. (Figure 2). As evident from the figure the aerial mercury concentrations at industrial sites decreased from year to year, reaching a level close to 0.01 mg/m³.

The observed quantities of mercury present in contemporary industrial establishments do not emphasize the significance of data contained in this chapter. Analysis reveals other facts especially important to the hygienic evaluation of the occupational mercurialisin problem. Thus, currently, sanitary
supervision is included in the sphere of activity of the industrial physician and applies to objects studied earlier and potential "mercury hazards," which, previously have not attracted the attention of hygienists.

The problem of mercury as an air pollution source on the working premises of electric power stations has almost never been discussed in the literature. Only in one study carried out by personnel of the Thar-kov laboratory of the All-Union Institute of Labor Protection VtSFS do we encounter an understanding of the presence of mercury in the air of a machine shop at an electric power station (V. P. Mayevskaya, I.S. Naumova, Ye.I. Lysenko, 1956).

The problem of the escape of mercury vapor into the air of work zones under conditions at heat generating stations was recommended by us for special emphasis. At the Kiev Electric Power Station, in pipe and boiler rooms and also in chemical water purification plants, mercury was observed in concentrations of 0.02 - 0.05 mg/m3. The basic factor determining the potential danger of the penetration of mercury into the air of these shops is the use of differential mercury-filled manometers for measuring liquid, steam, gas, pressure flows and also liquid levels in both open and closed reservoirs. These manometers are used in all branches of industry, but most widely in these power stations. Here they are employed in boiler rooms and very often in chemical water filtration plants. Observations have shown that although mercury in flotation devices does not contact the surrounding air, the manometer is connected with a sampling attachment by a steel impulse tube that, during use, can under some circumstances release mercury into the air. This takes place during the disconnection of the manometer during testing (not less than twice a year) and also in connection with necessary repairs.

These manometers constitute a special danger under power station conditions when used as level indicators for open reservoirs. In such cases one of the tubes is open and the mercury contained in the manometer contacts the surrounding air, contaminating it. The hazard of the latter is exacerbated in cases of sudden transmission of pressure changes which can eject the mercury out of the manometer into the site.

In the turbine shop, besides differential manometers, there are other mercury air pollution sources. Here, in connection with the technological exploitation of the power station in each turbine there is a mercury vacuumeter for measurement of vacuum in the condenser. In connection with this, one tube of the vacuumeter is open, and if the surrounding temperature is between 28 - 35°C, mercury will volatilize intensely into the air.

In such cases when the industrial-sanitary physician maintains continuous supervision of working conditions in print shops, book and magazine shops, printing combines and other graphics installations, they naturally note the possibility of lead vapor effects, from the melting of lead in machine or hand typesetting processes. Simultaneously, as a rule, it usually escapes their notice that in graphics and printing production conditions there is a basic toxic factor connected with mercury vapor. Results of our studies undertaken at the "Radyanaka Ukraina" combine in 1950 indicated that the mercury vapor content of the air of linotype and stereotype shops often reached fairly high levels, 0.035 - 0.05 mg/m3. A significantly lesser concentration of mercury was discovered by us in the course of 5 - 9 years at this enterprise and also in four polygraphic and book and journal printing plants in Kiev. In the air of the shops surveyed the mercury content was 0.015 - 0.012 mg/m3, in neighboring work sites, 0.007 - 0.004 mg/m3 (average quantities). Our data agrees with the results of previous investigators of the Sanitary Epidemiological Station of the Kirov region of Moscow (G. A. Beylikhis, 1954) who detected 0.23 mg/m3 Hg vapor in the air of Moscow printing plants (until demercuriza- tion), and 0.045 mg/m3 (after the first demercurization), 0.01 mg/m3 (after the third demercurization). The source of aerial mercury pollution in these printing plants were automatic thermoregulators used in control of heating type metal for composition.

The mercury concentration on premises of an instrument calibration service, where there are significant numbers of mercury filled instruments, varies, according to our data over a relatively wide range, from 0.0076 - 0.095 mg/m3.
The service personnel, repairmen (technicians and engineers), inspector (supervisory) can be affected by mercury vapor over a prolonged period. This service thus falls into the purview of the Sanitary Epidemiological Station, as will be shown below, since significant contamination of premises with mercury carried by service members in their "shifts" about the city occurs.

The Bureau of Instrument Testing is related to the instrument repair service. Aerial mercury vapor concentrations in work zones of these premises varies within similar limits. Thus, by our data, the mercury vapor concentration in the barometric department varies between 0.007 - 0.036 mg/m³ (an average of 0.025), and in the test chamber about 0.0085 - 0.02 mg/m³ with an average quantity of 0.01 mg/m³. Employees of this bureau and also in analogous regulatory departments (instrument testing, inspection and repair) has a significant number of mercury-containing devices on the premises. The Bureau of Hydro-meteorological Instrument Testing and the Division of Weights and Measures also have facilities in the city.

Mercury fills the "memory bloc" of EDP machines where it is contained in metal tubes 1.5 in in length and 3 - 4 cm in diameter.

Thanks to the presence of mercury, slow impulses are generated necessary for the remembering" of information. Periodically metallic mercury leaks from pipes and is thoroughly filtered and cleaned. During these operations the air of the site can be contaminated by mercury vapor.

Our data shows that the aerial mercury content of the Computing Center, AN USSR is 0.025 - 0.034 mg/Hg m³. Each pipe here is filled with 5 - 6 kg metallic mercury and all work with mercury takes place in a separate site equipped with exhaust installations. Mercury is purified once every three months.

Studies of working conditions in blueprint shops (L. L. Gorokhod, 1936, 1941) revealed that measurable traces of mercury were left and increased after blueprinting operations employing mercury lamps which were often the source of mercury vapor air pollution. Investigations by the Industrial Sanitation Laboratories of the Odessa Municipal Sanitary Epidemiological Station on air samples from blueprint shops revealed mercury in the air of about 0.2 - 1.2 mg/m³. L.L. Gorokhod concluded from these data that blueprint shops should undergo periodic demercurization. Workers in these shops should be examined periodically in the dispensary. Strictest precautions should be applied to the reinforcement of mercury lamps and general prophylactic measures (exhaust ventilation, adequate shielding, etc.) are needed.

Our blueprint shop studies in Kiev confirmed the presence of mercury vapor in the air. However, these concentrations were very low (0.015 - 0.03 mg/m³).

Not long ago highly toxic mercury compounds were used in the building trades. Ethylmercuric phosphate especially was used as a disinfectant.

A water-alcohol solution of this compound (0.05%) was usually prepared as a 30 - 50% solution for use at these sites for antisepsis. Thanks to the volatility of the ethylmercuric phosphate the air of the work zone contained comparatively high quantities of mercury not only during the mixing of the solution but during its later use and in the storage and transport of the preparation (up to 0.12 mg/m³). Prolonged presence of the compound (1 - 3 months) was noted in the air at sites treated with the antiseptic. This is explained by the slow release over several months of ethylmercuric phosphate vapors (in an experiment, 27 - 45 days). It is thus necessary to remember that wooden objects treated with the antiseptic contain mercury compounds. It is also evident that ethylmercuric phosphate in relatively high concentrations is also found in the air of neighboring sites.

Mercury in the Air of Electrical Transformer Sub-Stations

The continuous growth of cities and with them, urban electric transport, electrified railways, the increase in energy consumption of industrial
enterprises demand further networks of transformer substations which continuously "direct" the power necessary for equipment operation.

Important to the proper operation of these transformers are the mercury rectifiers used in a series of necessary technical and economic roles because of high field strength coefficient, low bulk, easy triggering, and comparatively low depreciation. Mercury rectifiers have the definite drawback of the possibility of intensive contamination of the air of production facilities with mercury vapor, however.

Results of long-term investigations of the air environment and the hygienic evaluation of specific operations in the exploitation of rectifiers at transformer substations for municipal electrified transport are discussed below. A series of railway substations and the substation of one of the biggest industrial enterprises where mercury rectifiers were set up in shop for electrolytic chlorine production are included.

Overhauling and repair of mercury rectifiers, is associated with necessary manipulations of rectifier parts contaminated with mercury, and despite precautionary safety measures, the air of the work zone is penetrated by comparatively large quantities of mercury (Figure 3), and metallic mercury also falls on the floor, equipment, instruments, furniture and special clothing, etc.

The comparative mercury concentration in machine shops compared to that of overhauling departments testifies, according to the data of many authors, to intensive contamination of the latter. B. B. Bykhovskiy and V. A. Naydenko (1957) observed at rectifier repair sites mercury concentrations of 0.048 - 0.26 mg/m³ V.P. Bogatyrev and S.A. Boytsov (1954) found even higher mercury concentrations in overhauling sections of the Moscow metroplitan substation, up to 0.45 - 1.25 mg/m³.

There is no unified opinion in the hygienic evaluation of form-vacuum pumps as sources of contamination of the air of electric transformer substations by mercury vapor. Presently a majority of authors consider the pumps to be an intensive source for the release of mercury vapor in the air (F.P. Senkevich, 1950; M. Ye. Yeventova and I.B. Kogan, 1936; 1938), other investigators (M.V. Yakovenko, 1953; D.V. Kazakevich, 1950) say the opposite. F. P. Senkevich observed mercury in concentrations of 0.1 - 0.15 mg/m³ in the exhaust pumps at substations in the Southern Ural railroad before casting and 1 mg/m³ after casting. The investigations of M. Ye. Yeventova and I. B. Kogan showed 0.36 -
0.28 mg/m³ V. P. Bogatyreva and S. P. Boytsov, 4.25 - 12 mg/m³ in ordinary working conditions with formvacuum pumps and 16 - 17.17 mg/m³ during casting.

It is suggested that the suction of air from containers in machine shops is the condition that determines significant contamination of the air with mercury vapor and is confirmed by O.M. Chachanidze (1954), M. Gizhdaran (1954), M.H. Gimadeyev (1958), V.G. Shalimov and V. A. Novitskiy (1955).

H. V. Yakovenko in stressing the role of these pumps as powerful sources for the release of mercury into the air stated that air that emerged from rectifiers contained about 0.00042 - 0.00065 mg/day (rectifier casting).

Since the quantity of mercury released in a day from the pumps (0.00042 - 0.00065) is insignificant with respect to the total volume of the machine shop (an average of 325 m³ per rectifier) it is practically unnecessary to notice it. It is impossible to agree with this conclusion. First, we have already emphasized that the prevention of mercury hazards requires not only general preventive measures but protection against specific intoxication; the task included in the prophylaxis of nonspecific "hidden" phenomena of the toxic effect of mercury as a low intensity factor. In connection with this, convenient sources of released mercury ought to be observed constantly and preventive measures taken. Secondly, the aerial mercury concentration around the pump site increases in comparison with the concentration prevailing before pump operations, and even "before" the mercury concentration is a comparatively high quantity. Thirdly, considering the physical properties of mercury vapor, it can enter the air quickly. Significantly, in a series of cases of pump operations, interactions occur not only involving the dynamics of mercury content in the air of machine shops, but also the mercury vapor level in neighboring work sites (control boards, accumulators, belt feeds). Our special calculations based on the work of E.M. Zamakhovskaya (1954) established the possibility of the release of significant quantities of mercury during pump operations, exceeding the quantities set forth by M. V. Yakovenko.

Thus, formvacuum pumps of mercury rectifiers are mercury vapor contamination sources at working premises of transformer substations. The significance of this fact is increased in that, such pumps operate continuously daily until repaired or overhauled.

Vacuometers are also mercury vapor sources at transport substations. Mercury evaporation originates in the mercury mirror of the vacuumeter which abuts the atmosphere. Additionally there is possible contamination of the machine area floor with mercury from the vacuumeter which can then contaminate adjacent equipment. A sharp pressure drop of breakage can flood the reservoir of the vacuumeter with mercury (compression manometer) and mercury can evaporate from the device.

The preceding explanation of the basic mercury vapor penetration sources at electric substations should not be considered complete, unless, in conclusion, we address the possibility of "secondary" air pollution sources. There is the problem of residual or sorbed mercury. These "secondary" sources are extremely significant hygienically. To a significant degree, they determine the level of mercury air contamination at working premises and indicate the sanitary status of one or another mercury object, enabling successful characterization of the sanitation of an enterprise (which will be treated at the end of this chapter).

Working conditions at electric transformer substations are determined by: the number of work sites at these substations, scale of production equipment, working ventilation, microclimate parameters, etc.

In a majority of cases the substation is divided into separate locations for machine shops, overhauling departments, accumulators. They have cement or asphalt flooring and are equipped with mercury rectifiers (most often RO-600's), control points and distribution installations. In all substations studies there were ventilation devices, primarily exhaust types. They were insufficiently effective in most cases because of large volumes of air movement on the one hand and the presence of mercury in the respiratory zone of workers exceeding
permissible concentration limits, on the other. Further, in certain production
locations of these substations where exhaust ventilation functions, air movement
is insufficient.

Our data shows the average air temperature in the respiratory zone of the
substations studied is between 19.8 - 26.3°C, a temperature variance of 1-7°C.
The relative humidity is 60 - 67%. The average winter air temperature (when
ventilation is disconnected) is 14 - 18.8°C. One should consider the possibility
of some air temperature increase at the cost of heat loss from the rectifier
body at the time of use (35.4°C) and especially during casting (55 - 50°C).

These data indicate that production microclimate conditions at machine locations
are not sharply defined by meteorological parameters obtaining under general
conditions. Nevertheless, a series of studies (D. V. Kazakevich, et al.) point
out the danger of air temperature increases at substations. This proposition,
however, is not confirmed by results of analysis done by D. V. Kazakevich
himself. Analysis of our data on the existence of a definite parallelism between
increased air temperature and mercury level contained does not always permit
establishing the presence of significant differences between data obtained at
different periods of the year.

One can suppose, by our data, that air temperature increase generates increased
mercury vapor concentration, primarily in cases when the machine shop premises
of the substation are contaminated by "residual" and sorbed mercury. The
stability of D. V. Kazakevich's results in winter and summer, and our data
relating to the relative persistence of aerial mercury content, obtained upon
the presence in machine shops of < 0.015 mg/m³, can explain the relative
cleanliness of these premises, rather than the fact of the presence of mercury
vapor in the presence of such a stable mercury source as made up by the action
of two pumps - mercury and formvacuum.

In concluding the survey of the preceding materials characterizing the state of
the air at the substations, we should stress that mercury vapor is detected in
the air as a byproduct of sanitized and inhabited locations. In a series of
related cases the mercury concentration in the air of these premises exceeded
permissible limits, which agrees with literature data. Thus, B. B. Bykhovskiy
and V. L. Naydenko took twenty air samples and in fifteen found mercury
concentrations of 0.021 - 0.075 mg/m³. V. P. Bogatyrev and S. P. Boytson found
higher concentrations 0.18 - 0.23 mg/m³ (various sites). The mercury level in
these places as a rule, reflects the general contamination level of the entire
premises (machines, overhauling and repair departments). Our data concerning
aerial Hg contamination in sanitized and other adjacent places reflect the
observations of some other researchers. An increased aerial mercury content in
the work zone occurred not only during the casting process but during overhaul
periods.

Comparison of aerial mercury concentrations at overhauling departments before
and after rectifier overhauls indicate that, in the latter case, these
concentrations increased 2 - 12 times. It is emphasized that, at those
substations where there are no overhaul departments and overhaul of rectifiers
occurs near the machines, the mercury content increases to a greater degree, an
average of 4 - 15 times. Finally it is necessary to note also that the increase
in aerial mercury content of the work zone which we established in the forming
period when the rectifier is cut off from air, contains mercury vapor, which,
without preliminary purification enters the working zone of the machine area. In
these cases mercury content increases 3 - 5 times, not only near the rectifiers,
but on benches in work places.

Remember that mercury diffusion pumps continually discharge gas from the
operating rectifier. The latter, along with mercury vapor, deposits in
previously emptied containers and there is a significant build-up of mercury
vapor.

There is discharge of air saturated with mercury vapor, especially in the
casting period. To a significant degree, it determines the presence of mercury
in the air of the work zones, and is confirmed by data presented on conditions
prevailing before and after casting. These data agree with results of observations of M. M. Gimadeyeva (1958), on labor conditions at electric transformer stations in Kazan.

Thus, from the point of view of industrial hygiene of specific substations their features and significance as objects of preparatory and continuing sanitary supervision, are characterized by four basic sources of possible mercury penetration of the air of work zones:

1. The process of opening, overhaul and repair of rectifiers.
2. The casting process.
3. The process of removing air saturated with mercury vapor from preliminarily evacuated containers.
4. MacLeod vacuumeters, from which metallic mercury can be sprayed, contaminating neighboring locations and equipment.

Among the objects studied by us was one of the substations of a big chemical enterprise. This substation engaged in electrolytic chlorine production. It has, from the hygienic point of view, much in common technologically with the operations described above. The latter is distinguished primarily by the use of Brown-Bovery rectifiers and the possibility of simultaneous penetration of the work zone by chlorine from the basic work site.

From the hygienic point of view the Brown-Bovery rectifier is distinguished by its vacuum system seals (at operating anodes, points of entry for electric conductors, at the ignition anode, etc.) with exposed mercury surfaces in the seals (so-called mercury condensation) with indicated levels. In all of the four functioning departments at the substation studied, the rectifiers include 48 such condensation points. The area of the exposed portion at the indicated level is 1 cm². Our observations indicate that in the exploitation process of Brown-Bovery rectifiers, the exposed mercury surface is a continuous source of mercury vapor generation. In work with these devices, the temperature at the condensing site reaches 60°C and mercury often leaks out, contaminating the air of the work zone. This provides an especially significant study for the hygienist and there is room for improving the negative characteristics of the rectifier. This points out the desirability of a condensation space between the vacuum chamber and pump since the air output of the Brown-Bovery-type construction contains a larger quantity of mercury vapor than do domestic rectifiers. In such constructions the evacuation system of the vacuum pump works round the clock. Evidently more rational from a hygienic standpoint is the construction of the vacuumeter, filled with mercury, circulated by a special piston during use. When the latter remains motionless the mercury can escape during common use of the vacuumeter through a variety of outlets.

Our studies revealed the presence of mercury vapor in the air in concentrations that, as a rule, exceeded 0.01 mg/m³.

Thus, the preceding materials indicate that, in case of use for electrochemical work, mercury devices of Brown-Bovery construction, there will be an elevated mercury concentration in the respiratory zone of workers, higher than that prevailing during the use of RV-20, RU-600, RNVM and other devices. Therefore, the need for substitution of other devices for the Brown-Bovery-type of construction is evident. Domestic rectifiers employ resin or porcelain isolators in mercury condensate zones.

Of special significance is the fact of periodic presence in the air of the machine area and overhaul shop of both mercury and chlorine vapor in concentrations lower than permissible (0.001 mg/l by an average of 2 - 3 times (0.0003 - 0.0005 mg/l). Naturally, at industrial sites containing transformer substations, the combination of mercury and other toxic substances released into the air near the substation or from industrial sites not far removed from it can enter the machine or other areas for a number of reasons. In a given case there was an exhaust ventilator shaft through which air currents from the machine area located four m from the lighting fixtures of an electrolysis shop pervaded by chlorine, near the air outlet of the substation. Evidently the two currents met
and, via the ventilation system, chlorine contaminated the substation premises. This does not exclude the possibility of recirculation of mercury vapor.

The risk of harmful action on the bodies of workers of a combination of mercury and chlorine at the substation increases with the air temperature which is, in winter 24 - 25°C, and in summer, 29 - 31°C.

Data presented on the hygienic characteristics of the "mercury hazard" under conditions of transport and industrial transformer stations indicate the real danger from the action of low concentrations of mercury for personnel employed at the substation.

Features of Labor Conditions in Laboratories Where Mercury is Used

Among the varieties of work, industrial processes and operations, connected with the possibility of worker contact with mercury, Laboratory work is a priority. (S. Yu. Yelovich, M. M. Tuchenko, 1937; Ye. N. Telishevskaya, 1941; I. I. Atlichenkov, 1953; M. H. Gimadeyev, 1959; and others). It is known that under the conditions of many laboratories -- industrial, scientific, experimental, production and academic -- mercury-containing devices, apparatus and instruments are widely used. Among these are technical thermometers, chemical TL-2, digital TL-3, Beckman system TL-1, direct and angled, mounted and unmounted, TTR0, TT-10, TTRUO and others, room thermometers TB-2, special thermometers for a variety of instruments and devices (TU-2, TU-7, etc.).

Other mercury-containing items in laboratories include: automatic thermoregulators, contacts, manometers, vacuum diffusion pumps, manovacuumeters, differential manometers, and other control, measuring and regulating devices. Contact with mercury is possible through a number of activities, varied in character, in these laboratories from large industrial to small academic.

Of great significance in this respect is the universal character of laboratory operations, adhering to one or another degree, to the procedures at our laboratory. One of the most widespread operations is mercury purification from its adulterants. In typical cases, the procedure is as follows:

1. Removal of mechanical admixtures by filtration through paper filters;
2. Washing in 10 - 20% caustic potash KOH or NaOH, to destroy organic contaminants, and the removal of metallic impurities;
3. Washing in distilled water;
4. Oxidizing impurities at high temperature or dissolving them;
5. Heating under reduced pressure;
6. Heating in degassers or fractionators.

According to our observations, filtration of mercury to remove mechanical impurities is done in several laboratories without adhering to any safety measures, such as using the exhaust hood. In the filtration process, it is possible that mercury spilled during pouring can evaporate from exposed mercury and glass surfaces. It is also possible to contaminate the premises while washing mercury with 10 - 20% KOH, NaOH, or distilled water.

The purification of mercury by oxidation from impurities dissolved in it is done in laboratories with oxygen, ozone or air. Oxidation with ozone is done in a Rozanov apparatus. The principle of the method is in the bubbling of gas through a portion of mercury, oxidation of the metallic impurities with subsequent flask filtration. In the oxidation process, mercury vapor can enter the air and atomize in it. There drawbacks can be eliminated by dissolving the impurities; beside that, the solution purification of mercury is more effective than oxidation. Dissolved impurities are extracted by passing mercury through a weak nitric acid solution or nitrous oxide of mercury. These solutions in the laboratory are commonly poured through various types of columns (Mayer column, Desha automatic column, Dickson and Makay, Yefremova and Popova, Dbozhak, etc.). Passing purified mercury through glass valves, incompletely sealed, can contaminate benches and floors with mercury.
After purifying mercury by washing it with distilled water it is then dried to remove traces of water. In most laboratories mercury is dried by heating it in porcelain vessels over an open flame. Naturally, there is intensive evaporation of mercury vapor into the air. The purity of mercury is confirmed by controlled laboratory analysis. In cases of impurity the purified mercury is reheated in a Hewlett, Pugachev or Rozanov apparatus in which there is no danger from heating with respect to hygiene.

In speaking of the potential danger of micromercurialism under laboratory conditions, and also of the possible sources and means of entry of mercury into the air, note that metallic mercury is usually stored in the laboratory without observing the proper hygienic regulations.

At industrial enterprises where relatively large volumes of mercury are used it is usually stored in steel tanks (30 - 40 Kg each) screwed shut with steel stoppers. In laboratories where the mercury volume used is significantly less, it is usually kept in glass vessels, under a layer of water (rarely under glycerine), closed with resin or cork stoppers. The enumerated "methods" of preventing air contamination by mercury are not very successful. In laboratories where mercury is stored in glass vessels, grinding of stoppers can release mercury into the air in the absence of all other sources, resulting in the continuous presence of its vapor in 0.003 - 0.0075 mg/m³ concentrations. Evidently, abrasive sides of stoppers which seal glass mercury storage vessels are not smeared with vacuum grease since the latter contaminates mercury. Yet the use of vacuum grease is necessary for providing hermetic sealing of glass vessels.

Only in a few laboratories is mercury stored under exhaust hoods. As a rule glass vessels containing mercury are kept on laboratory benches, cabinets and shelves with other chemical substances and reagents. Conditions in the cabinets are unfit for repair of mercury containing instruments or parts of such instruments.

A significant source of airborne mercury contamination is instruments having exposed mercury surfaces. Among these are: pressure recording devices, manometers, vacuumometers, flow meters, suction gages, etc. In case of sharp pressure variations mercury escapes from the instrument. Additionally mercury pressure devices release mercury into the surrounding air from open vacuumeter mirrors and V-form manometer parts. Pouring from the instrument also releases mercury.

We have already pointed out the wide distribution in laboratory practice of vacuum creating devices. It should be stressed that, under these conditions, the use of mercury is not required. There exist oil, ion and molecular vacuum pumps. However, laboratories mainly use mercury vacuum diffusion pumps. This is explained, on the one hand, by the high vacuum capacity of mercury pumps, and on the other by their simple construction and high degree of recipient purity.

During pump operation, mercury must be present in exhaust gases. Thanks to insufficient diffusion barriers in the pump, this is the most significant factor in the contamination of working premises with mercury vapor.

Speaking of vacuum apparatus, it is necessary to discuss simultaneously other forms of mercury use in them. First is mercury's use in seals because of its high specific gravity. The seals are used to maintain a sufficient degree of vacuum. Their basic hygienic insufficiency is mercury leakage from the seal surface and also the possibility of its expulsion during improper or unskilled operation or preoperative preparation.

An analogous defect is present in vacuum valves, which, when improperly fitted, permit mercury vapor contamination of the air.

In electronic laboratories the most widely used mercury-filled instruments are mercury cup contacts, mercury rectifiers, mercury- toluol contact breakers and polarographs. Despite a series of technical achievements, these devices are
defective from a hygienic standpoint, and, under certain conditions, are transformed into sources for intensive discharge of mercury into the air.

Beside devices having exposed mercury surfaces, there is a definite danger from "sealed" mercury equipment. As a rule these are glass items, the destruction of which contaminates adjacent objects.

The first group is the most significant. To it belong all devices and operations during which mercury contacts and evaporates freely into the surrounding atmosphere.

The second group includes devices in which mercury is in enclosed spaces and are hazardous only upon mechanical destruction.

This can be divided further. Thus for example, mercury devices belonging to the first group are also subject to mechanical destruction with the release of large quantities of mercury.

Data on mercury vapor concentration in laboratories is contradictory and therefore it is hard to determine the conditions present in one or another laboratory profile, and consequently, in a complex of laboratory equipment and operations. Nevertheless, it is expedient to analyze these data in order to compare their results with our observations. The data are presented for convenience in tabular form (Table 8).

First of all, pay attention to the high laboratory mercury vapor air contamination, exceeding by many times 0.01 mg/m³, the maximum permissible quantity, at production sites of industrial enterprises. The reason for such high laboratory mercury contamination levels is, according to the data of many authors, firstly, disregard of rules for handling mercury, and secondly, insufficient laboratory equipment fulfilling hygienic requirements. It is interesting to note that of the materials presented, there is no visible difference in the amounts of aerial mercury concentration in cases of specific violation or neglect of mercury work rules when these rules are not observed daily. In this respect, the observations of M. M. Gimadeyev are indicative. His data shows that, in factory laboratories, when equipment and premises are properly maintained, the source of intensive mercury contamination in the air is a container, strongly contaminated with spilled metallic mercury. In one of the university metallurgical laboratories, Z. Goldwater and co-authors found mercury continuously present wherein the only mercury vapor source in these premises was a vacuum device which periodically released mercury saturated gas into the laboratory.

The preceding examples could be extended. They all indicate that successful prophylaxis of mercury poisoning under laboratory conditions may occur if there is complete prevention of circumstances in which the air becomes contaminated with mercury vapor.

We will make a brief presentation of our data characterizing the mercury vapor content of laboratory air. Note that the great frequency of positive results of analyses for the presence of mercury and its relatively high concentration is independent of laboratory profile. Thus, only in two scientific institute laboratories was it unrecorded. Tests showed trace amounts of mercury in six of the observed laboratories. In the rest of the samples the mercury vapor concentration varied between 0.0045 - 0.07 mg/m³, in which the quantity detected depended upon the time the sample was taken during mercury operations or in the period immediately preceding them. Thus in the Experimental Laboratory of the Division of Mechanization of Hydrotechnical Operations the air sampling period in one case out of seven fell during the use of we-form manometers and DP-430 differential manometers, in the other periods, during their use under experimental conditions (15 samples). It appears now that in the second case the respiratory zone mercury content for scientific personnel and laboratory workers working in the laboratory varies from traces to 0.035 mg/m³. In the first case the levels of these concentrations and their range were different, from 0.009 - 0.06 mg/m³.
As a rule the higher aerial mercury concentrations occur in the respiratory zone of laboratory workers immediately after manipulations involving purification of instruments containing mercury or in filling and storage.

Increased mercury content (exceeding two to four times the 0.01 mg/m³ limit) was recorded in the Laboratory of Metallic Gases of the Electric Welding Institute imeni Akad. Ye. O. Paton. Here several vacuum devices for the determination of gas content of metals operate — installations for the gas analysis of aluminum, steel, etc. Additionally, this laboratory employs a mass spectrometer equipped with a mercury diffusion pump.

Still higher mercury concentrations (0.03 — 0.065 mg/m³) were observed by us in the chemical analysis laboratory of "Kievgeologii", in which polarographic determinations of copper, cadmium, zinc, magnesium, and a series of other chemical elements was done. Our observations showed that frequent manipulation of "exposed" mercury occurred in this laboratory, such as electrolytic purification, filtration, and washing in 10% nitric acid solution. These manipulations and also the ignition of various types of rock for spectral analysis contributed to the high mercury content in the air of this laboratory.

A significant mercury vapor source in many laboratories was a Favor system gas analyzer used in the determination of 0.5 — 2% methane content. The following was noted: before operation of the Favor apparatus, the aerial mercury vapor content in the laboratory varied between trace amounts to 0.008 mg/m³ (average concentration, 0.005 mg/m³); after beginning instrument use and during subsequent operations there was a sharp rise in aerial mercury content reaching levels on the order 0.055 — 0.07 mg/m³ (average concentration, 0.06 mg/m³).

### Table 8

<table>
<thead>
<tr>
<th>Laboratory name</th>
<th>Excess over 0.01 mg/m³ Hg (in tests yielding positive results)</th>
<th>Number of persons showing intoxication</th>
<th>Author and year of investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory of the Karpova Institute</td>
<td>8 - 33 times</td>
<td>In 5 workers with subjective complaints, chronic mercury poisoning appeared</td>
<td>Ye. N. Telnhevskaya, 1941</td>
</tr>
<tr>
<td>Laboratory of the Kharkov plant KIP</td>
<td>In specific isolated laboratory premises 5 - 30 times</td>
<td>In 29 of 308 workers, there was chronic mercury intoxication</td>
<td>G. L. Sklyunakaya-Vasilevskaya, V. I. Yefimov, 1941</td>
</tr>
<tr>
<td>Physical and chemical laboratories of institutes, plants, and factories in Leningrad</td>
<td>In 58% of cases, 2 - 9 times. In 38% of cases, 10 - 120 times. In 3.8% of cases, the mercury content did not exceed permissible limits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institute of Soil Research</td>
<td>35 - 700 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental departments</td>
<td>400 - 600 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiology</td>
<td>60 - 90 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Chemistry</td>
<td>17 - 60 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Chemistry</td>
<td>11 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Chemistry</td>
<td>30 times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Chemistry</td>
<td>17 - 50 times</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As a rule the higher aerial mercury concentrations occur in the respiratory zone of laboratory workers immediately after manipulations involving purification of instruments containing mercury or in filling and storage.
During Favor system gas analysis operations there was continuous air flow through a mercury-filled pipet, allowing release of vapors into the air of the laboratory work zone.

Mercury evaporates continuously from the instrument flask and the mercury manometer. Also mercury is poured out of the instrument every day at close of work and, before work, is purified by filtration and then replaced in the system. It is these additional manipulations that facilitate mercury air contamination.

Mercury contaminates places where electron microscopy is done. Modern electron microscopes are widely used in all branches of science and technology for the observation of filterable viruses, organic molecules, metal films, etc. As is known, all the space in the electron microscope in which electrons move is a vacuum. The latter is achieved by a mercury diffusion pump, the exhaust of which contaminates the work zone of the operator. Our data show the presence on the premises where mercury pumps are used in electron microscopy, of mercury concentrations on the order of 0.0055 - 0.036 mg/m³. Larger amounts (0.02 - 0.1 mg/m³) were observed earlier by S. M. Gorodinskiy (1950). Both his and our data do not indicate the effects of other metals on this problem. Nevertheless, when the electron microscope is operating there is a potential hazard of mercury affecting personnel in these laboratories as shown in a series of cases discussed below.

Mercury is very persistent in the laboratories of higher educational institutions. It is important to note the presence, as a rule, of high mercury concentrations in the air of laboratories of academic institutes in comparison with scientific research institutes and the significant trend to lowered levels through the years. In 1948 - 1949 the mercury content in the air of laboratories of most departments varied within the limits of 0.01 - 0.2 mg/m³, most concentrations being in the range of 0.035 - 0.09 mg/m³, then in the following years lower quantities were found, ranging between 0.01 - 0.07 mg/m³, but most remained at a lower level, on the order of 0.01 - 0.035 mg/m³. Such a tendency toward aerial mercury content decrease in academic laboratories reflects the general decrease in the action intensity of external toxic agents. The latter as already noted, is connected with increased emphasis on problems of prophylaxis.
of occupational intoxications, and the increasing effectiveness of health measures. However, note that this general tendency toward diminution of aerial mercury content in academic work zones in this case has fallen behind that in all other cases. Special emphasis is placed on the juxtaposition of this data with previous materials characterizing the level of mercury contamination in electric transformer substations, shops of industrial enterprises and in or on other industrially-connected objects. Connections of this type do not negate the position that today there is an apparent paradox in that the aerial mercury concentration in laboratories is higher in many cases, than at production sites of industrial enterprises.

Mercury in Medical Institutions And in Medical and Biological Laboratories

In connection with the use of mercury, its compounds and instruments containing mercury in medical institutions it is possible for medical personnel at hospitals, rest homes, sanitary epidemiological stations, drug stores, laboratories of medical scientific research institutes, clinics and departments of medical schools to contact mercury. Hygienic investigation of these places revealed the presence of mercury vapors (primarily in thousandths of a ing,, 0.006 - 0.03 mg/m³ on the premises of clinics of therapy, pediatrics, infectious diseases, surgery, obstetrics and gynecology, and also in the laboratories of departments of normal and pathological physiology, biochemistry, pharmacology normal anatomy, operative surgery and topographic anatomy.

On the premises of the latter two departments mercury vapor occurred primarily in Stephanis instruments used for the pressurized injection of lymphatic vessels. Let us note in the air of such premises there was observed, simultaneously and continuously, formaldehyde as well as mercury vapors.

Mercury vapor was continuously present in diagnostic offices, clinics, biochemical and bacteriological laboratories, and physical therapy rooms.

Note aspecially that, in addition to doctors, the number of average medical and employees continuously working in these premises periodically exceed the number of people in therapeutic institutions of various types who must follow the hygienic requirement for use of mercury and mercury containing instruments.

Most often in these institutions, and also in medical and biological laboratories arterial oscillographs, gas analyzers of various designs, thermometers of bacteriological thermostats, bactericidal lamps, mercury-quartz burners (stationary and portable), mercury contacts and automatic thermoregulators in diagnostic and therapeutic apparatus are used.

The presence of mercury at therapeutic facilities may be connected with the use of its compounds, for example, mercury dichloride. The latter is still known to be used as an antiseptic substance (swabbing the skin, disinfecting mucous membranes and wound surfaces), for the disinfection of dressings, surgical instruments, linens and medical furniture.

Mercury compounds and mercury-containing instruments are also used in clinical and morphological laboratories during biochemical and histochemical research (electrophoretic determination of protein fractions, thiol compounds, revealing them in the microstructure of tissues, etc.); in laboratories of sanitary-epidemiological stations for the conduct of a series of chemical analyses (mercurimetric method of determining chlorides in water, determination of ammonia and ammonium salts with Vessler's reagent, volumetric analysis of air for oxygen and hydrocarbon determination and a complete series of other determinations).

The contamination of drugstores by mercury vapor is most frequently connected with the presence of metallic mercury, utilized frequently for the preparation of various ointments (antiseptic, anti-inflamatories and adsorbents).

The most universal mercury air pollution source at medical institutions is the metallic mercury from easily breakable medical thermometers. Thus, in wards of one of the regional hospitals, about 150 medical thermometers were broken in a
year, and mercury vapor was found there later in concentrations of thousandths mg/m³.

We noted that mercury vapor from broken medical thermometers was detected in reception rooms for pre-school children at health facilities (N.F. Form, Ye.Ye. Malyarenko, 1959).

A special risk of chronic mercury effect on working personnel today lies in the wide use of amalgams as a filling material in dental practice.

Regarding amalgam carriers, there is presently a link between amalgam weight and urinary mercury content (Z. Goldwater, 1966), although the possibility of the harmful action of mercury, released from the filling, can be considered predominant (S. I. Kozlovskiy, 1965).

The technique of preparing fillings from amalgams (heating copper amalgams, grinding the mass during which mercury contacts the air of the premises, etc.) is such that it contains in itself the possibility of contaminating the dental office with mercury vapor. The risk is not only from vapor. In the grinding process and other operations it is possible that droplets will fall on the work table and the floors and will contaminate fingers and protective clothing with mercury. If slabs containing mercury amalgam admixtures, are prepared incorrectly, they can "spatter" from heat-caused explosion. Additionally under stomatological office conditions, as a rule it is unsatisfactory to collect pressed-out mercury. It is better to store it under a layer of water which does not, however, constitute absolute protection of mercury from vaporization. At the same time stomatology offices do not take all necessary measures for improving working conditions. The basic reason for this is insufficient acquaintance of physician stomatologists and administrators of stomatology polyclinics with these facts and with the results of recent observations by hygienists here and abroad. We will discuss some of these.

The Yaroslavl Sanitary Epidemiological Station conducted hygienic investigations of dental offices at several walk-in and polyclinics. Air and swab analysis, from office walls, furniture and equipment revealed 0.03 – 0.17 mg/m³ mercury concentrations in air, and 0.000064 – 7.5 mg/cm² (swabs). In adjacent locations where no amalgam work was underway, the mercury concentration was 0.005 – 0.04 mg/m³. Copper amalgams made during filling construction were the sources. The walls and furnishings were apparently a secondary depot from which mercury gradually evaporated, entering the air anew. In two persons (a physician and a sanitation worker) who had worked in an environment containing 3-7 times the limit of 0.01 mg/m³, chronic mercury intoxication was diagnosed and they were directed to a therapeutic clinic for treatment. Later five persons in the dental office had a diagnosis of micromercurialism. Later it was observed in fourteen other employees of dental offices in the walk-in clinic. Material analogous in character was obtained by M. M. Gimadeyev (1958) in Kazan. In the air of a dental office at the Municipal Stomatology Polyclinic the author observed mercury vapor in the amalgam preparation area, the adjoining office and even in the corridor near the surgical office, the office of the head physician. In the plaster walls the mercury content varied between 0.08 – 0.012 mg/100cm² and in the plaster ceiling between 0.048-0.06 mg/100 cm².

M. M. Gimadeyev noticed that during pressing mercury continuously falls on the floor and forms an aggregate which vaporizes continuously, so-called fallow mercury.

R. A. Khutoryan's (1961) data showed mercury contamination of nurses' hands who had prepared metal fillings and of physicians at the Kirovograd Regional Hospital. The author's data based on several years of observation of the air in dental offices showed a mercury concentration between 0.03 – 0.17 mg/m³, and in smears from the hands of personnel, 0.003 – 1.35 mg/m³.

Table 9 shows the aerial mercury content of stomatological offices and adjacent locations obtained in various cities.
In the last few years, beginning in 1955, we systematically analyzed the air of dental offices at walk-in polyclinics, stations and several specialized therapeutic institutions, departments of stomatology of medical and post-graduate medical institutes.

Analysis of these results showed that the worker respiratory zone in a majority of offices surveyed contained mercury vapor. Only in 9 of the 48 offices studied was no mercury at all detected, in others there were traces. In these 9 offices no amalgams were used or their use was limited to children.

Especially interesting is past and present data (1960 - 1963) on the aerial mercury content of a series of offices. There is a trend towards gradual diminution in aerial mercury vapor content in stomatology clinics upon application of recommended prophylactic measures. Thus, the aerial mercury content in offices of the First Poldol'sk Hospital of Kiev in 1955 was 0.035 - 0.075 mg/m³, while in 1961 mercury was not detected there, although very low concentrations were present (0.004 -0.0055 mg/m³). Sometimes the mercury content of other work zones exceeded permissible limits 5 - 7 times despite attempts at preventing the escape of mercury vapor into the air. Often the presence of drawing devices for filling production necessitated cleaning of floors with a solution of manganese oxide, potassium HCl, washing furniture, windowsills and glass with hot soapy water.

The decreased aerial mercury concentration noted by us in 1961 is connected with the organization of a separate office for filling teeth. This office was equipped with an exhaust hood for preparing and storing amalgams and mercury and also with exhaust fans. This measure alone contributed greatly to the reduction of aerial mercury content. Also the Department of Therapeutic Stomatology of the Medical Institute had been in a place not designed for stomatological offices; there were no exhaust hoods where the fillings were prepared.

Investigations of the aerial mercury content dynamics indicated that high Hg concentrations persisted for years. Mercury-contaminated items included not only offices where amalgams were prepared and used by adjacent locations, primarily laboratories. Although very small quantities of mercury were detected it was continuously observed in the offices and reagent storage spots. The highest concentrations being detected where mercury and amalgams were kept. Sharp decreases in aerial mercury content was achieved by isolation of amalgam production and storage.

1961 - 1963 materials showed that concentrations varied between 0.008 - 0.025 mg/m³. There was a gradual increase in aerial mercury content between the first and second sampling in 7 cases (0.007 - 0.01 mg/m³), in 5 only traces were detected and in 12 samples no mercury was detected. Two years later there were negative results in only 5 samples and traces in 2. In the rest the mercury content varied between 0.008 and 0.025 mg/m³.

The preceding data shows that the amount of mercury in dental offices is variable not only over the years, but in different months or days. The amount of variation depends on the mercury evaporation intensity (i.e. temperature, air circulation time, presence or absence of ventilation, etc.). However, a specific determining factor is continuous manipulation of copper amalgams in work areas near dental chairs.

Dynamic investigations of the air before, at the beginning of the work day, during heating of the copper amalgam and during its use show that during heating the mercury vapor content at the site increases 3 - 5 times.

In the course of these and other investigations we established that in offices where more than five doctors worked, 14 - 32 teeth were filled. This agrees with C. G. Yaroshenko's data that in the stomatological department of the institute nine doctors filled 27 teeth. Therefore the multiple heating of amalgams makes possible the intensive mercury contamination of the air, the degree of which depends on the volume used.
The mercury level of the respiratory zone of dental personnel is usually higher than that in industry. The most striking example of this is that, in one dental office at a Leningrad clinic, where copper amalgam was used, the mercury content was higher than in the plant where it was prepared (Table 10).

As evident from the data in the table, despite the significant difference in mercury volume handled (at the plant, up to 20 - 28 Kg), the industrial mercury concentration was lower than that of the stomatological offices.

These and other conforming facts explain the absence of prolonged attention to the prophylaxis of mercurialism in stomatological practice.

It is known that persons working with mercury at industrial enterprises are subject to strict medical surveillance. These persons undergo periodic medical examinations for prolonged periods. Meanwhile, among dental employees, for whom work with mercury is contraindicated there are few. Notwithstanding this fact, there are, although briefly, ill persons in dental offices suffering from one or another oral ailment which renders them especially susceptible to the harmful effects of mercury. Let us remember that mercury is excreted by the mucous glands and often causes mercury-specific gingivitis and stomatitis.

### Table 10

<table>
<thead>
<tr>
<th>Object studies</th>
<th>Mercury evaporation source</th>
<th>Mercury vapor concentration mg/m³</th>
<th>Author's name and year of investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental offices of three Moscow polyclinic</td>
<td>Silver and copper amalgams, heated over a spirit lamp; spillage contamination of the floor</td>
<td>0.06-0.45</td>
<td>A. N. L'vov, 1937</td>
</tr>
<tr>
<td>Yaroslavl stomatology polyclinics</td>
<td>Amalgams contaminated by mercury sorbed out of the air from office walls and adjacent places with mercury contaminated furniture</td>
<td>0.026-0.07</td>
<td>E. V. Lileyev, R. S. Panfilova, M. S. Khlopin, 1955</td>
</tr>
<tr>
<td>Kazan stomatology polyclinics</td>
<td>Amalgams and various mercury-sorbed materials</td>
<td>0.056-1.52</td>
<td>M. M. Gimadeyev, 1958</td>
</tr>
<tr>
<td>One of L'vov's stomatology polyclinics</td>
<td>Amalgams, floors and walls contaminated by mercury spillage</td>
<td>0.03-0.04</td>
<td>V. V. Gupalo, M. C. Besh, 1958</td>
</tr>
<tr>
<td>One of Leningrad stomatology polyclinic</td>
<td>Flasks and cellulophane bags packed with copper amalgam, contaminated floors, walls, furniture and protective clothing</td>
<td>0.03-0.28</td>
<td>Ya. M. Buguslavskiy, 1958</td>
</tr>
<tr>
<td>Municipal Stomatological Polyclinic of Smolensk and dental offices of city polyclinics</td>
<td>Amalgams</td>
<td>Exceeded permissible limits</td>
<td>A. M. Prokhorova, G. I. Uporova, 1960</td>
</tr>
</tbody>
</table>
Mercury in School Classrooms

During the last ten years, hygienists working in different cities (Moscow, Kiev, Dnepropetrovsk, Khar'Kov, Novosibirsk, vil'nyus) frequently encountered facts emphasizing the potential hazards of mercurialism in general preparatory schools. Mercury vapor was detected in 66.4% of all physics classrooms and in 76.5% of all prep rooms of Moscow schools. A significant number of samples contained mercury at or above 0.01 mg/m³, the maximum permissible concentration established for industry.

Analogous data on the presence of mercury vapor in the air, although in somewhat lower concentrations, were observed in Dnepropetrovsk school physics classrooms.

* Minimum and maximum concentrations appear in the table

** In one of the dental offices of the polyclinic, the mercury concentration reached 0.86 - 1.52 mg/l and the office was closed by sanitation authorities. Later extensive repairs were made, involving the removal of plaster from the walls and ceilings, stripping the floor, and removal of mercury contaminated earth from the cellar.

### Table 9 - continued

<table>
<thead>
<tr>
<th>Object studies</th>
<th>Mercury evaporation source</th>
<th>Mercury vapor concentration in mg/m³</th>
<th>Author's name and year of investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirovograd Regional Stomatology Polyclinic</td>
<td>Amalgams, mercury contaminated hands of medical personnel</td>
<td>0-0.17</td>
<td>R. A. Khutoryan 1961</td>
</tr>
<tr>
<td>Stomatology offices of a series of therapeutic institutions in Kiev (walk-in clinics, polyclinics, hospital departments, stations and departments of the Medical Institute)</td>
<td>Amalgams, fallow mercury; contaminated walls, floors, ceilings, furniture and equipment</td>
<td>0-0.17</td>
<td>I. M. Trakhtenberg 1962</td>
</tr>
</tbody>
</table>

### Table 10

Mercury content in the air of a copper amalgam production shop in a dental office (data of Ya. M. Boguslavskiy, 1958)

<table>
<thead>
<tr>
<th>Copper amalgam production</th>
<th>Mercury vapor concentration in mg/m³</th>
<th>Dental office</th>
<th>Mercury vapor concentration in mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation and place of study</td>
<td>Min - Max - Average</td>
<td>Operation and place of study</td>
<td>Min - Max</td>
</tr>
<tr>
<td>Separation of copper powder</td>
<td>0.0025 - 0.0127 - 0.0066</td>
<td>Filling adult teeth</td>
<td>0.02 - 0.28</td>
</tr>
<tr>
<td>Amalgamation of powder</td>
<td>0.0026 - 0.027 - 0.004</td>
<td>Filling children's teeth</td>
<td>0.021 - 0.028</td>
</tr>
<tr>
<td>Packing the copper amalgam</td>
<td>0.04 - 0.021 - 0.011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(V. I. Petrov, Ye. B. Turovskaya, M. Ye. Obraztsova, 1962). They paid especial attention to the higher mercury content in the work zone of the prep rooms (taken at 0.5 m above the floor) in comparison to that at the respiratory zone.

Increased mercury vapor content was noted after setting up of and demonstration of experiments and instruments employing mercury. There is recent published material on the presence of mercury vapor in the air of physics classrooms in the Dnipropetrovsk schools Cl. N. Kushakovskiy, R. I. Teplitskaya, 1963). Analysis of these materials showed that, of the total number of air samples taken in physics classrooms, only 25% were mercury-free and in 23% the mercury vapor content exceeded 0.01 mg/m³. Analogous data for the prep rooms was 6% and 35%.

Air environmental studies of school premises in Khar'kov also confirmed the presence of mercury in physics classrooms and especially in their prep rooms CM. I. Chernyavskiy, H. L. Talpamatskaya, 1960).

The previous materials plus those of other authors CR. S. Khokhlova, 1956; A. V. Mitsel'makhev, 1961) indicate that mercury vapor air contamination of school physics classrooms is encountered fairly often.

Data on mercury vapor contamination of the air of chemistry classrooms is absent from the literature. Therefore we analyzed the air of chemistry classrooms: 143 samples were taken in classrooms and 118 in adjacent prep rooms in both new and long-established schools. Results showed that there is significant danger in prolonged use of mercury-filled instruments on these premises. Mercury vapor was observed in 83% of all samples taken (Table 11).

Note that half of the samples contained mercury in excess of 0.01 mg/m³ by a factor of two or more. It is evident that this concentration, the maximum allowed in industry, cannot serve as a hygienic criterion for the evaluation of school premises, where mercury vapor should not be at all.

In only 15 of the 76 school premises studied (6 classrooms and 9 prep rooms) was there no mercury discovered. In these cases experiments with mercury were not conducted and metallic mercury was not stored on the premises.

The basic source of mercury contamination of chemical classrooms is mercury vapor formed in the course of demonstrating mercury as an example of a liquid metal, leading to massive local mercury vapor contamination of the classroom. The danger of mercuric oxide use was shown (A. Stock, 1934) in that, at room temperature, it liberates mercury vapor into the air and, upon increasing the temperature from 20 – 30°C the aerial mercury content increases more than two times. This fact emphasized the need for protecting chemistry classrooms from this contamination source also.

Potential mercury hazards in schools are not limited to the above substances. In some schools we saw experiments employing mercury which were not in the prepared syllabus. Some untypical mercury compounds were found stored in prep rooms. Thus, in some Kiyen schools there were demonstrations of amalgam preparation. Nitrogen compounds of mercury were often discovered. Some solutions of mercury salts discharge mercury into the air at normal temperatures. Nitrates have this property and at high temperatures vaporization increases whether or not there is metallic mercury in the given solution.

In most of the new schools most chemistry classrooms are located on the second floor, under the physics classrooms. Since mercury vapor is heavier than air and the floors and ceilings of these rooms are not protected by mercury-proof paint or other mechanical barrier, or are usually not effective if used, there is the possibility of "sufficient" contamination of both chemistry classrooms and a series of rooms on the first floor.

Data on the mercury vapor concentration in air samples taken in school physics classrooms are shown in Table 12.
Thus, mercury vapor persists in the air of physics classrooms and prep rooms. In 111 (60%) of the classroom samples the mercury concentration was more than 0.01 mg/m³, and in some of them, exceeded 0.05 mg/m³, although only temporarily. It should be noted that these times were usually during demonstrations.

In a series of chemistry and physics classrooms results of samples taken before and after demonstrations involving mercury were analyzed. Mercury vapor content of the air rises sharply near the table at which the demonstration is conducted. (Table 13).

On succeeding days the aerial mercury concentration decreases gradually to the concentration observed before the experiment.

Note that, at all these premises and demonstrations involving "open" mercury there was a stable aerial Hg content.

Also, there was the presence of so-called "fallow" mercury in the sub-flooring of physics and chemistry classrooms, which upon evaporating, maintained high mercury concentrations in the floor.

"Fallow" mercury in structural elements and working furniture is sorbed mercury, deposited in structural elements, and then releases mercury vapor into the classroom. In Table 14 there is data on the mercury content of the surroundings, furnishings, and equipment of academic physics premises in which the mercury content varied between 0.007 - 0.03 mg/m³.

The presence of sorbed mercury explains those cases in which a single chemical demercurization was not effective. In these cases, the primary source, metallic
mercury, was removed but the above mentioned secondary sources must also be removed to achieve the final removal of mercury.

**TABLE 13**

<table>
<thead>
<tr>
<th>Where sample was taken</th>
<th>Mercury Concentration mg/m³</th>
<th>Addendum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Setting up the experiment</td>
<td>Second day after the experiment</td>
</tr>
<tr>
<td>Near the lab bench at the respiratory level</td>
<td>0.007</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>0.005</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>0.044</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Torralli's column experiment (Class VI), a demonstration of the relation between volume and pressure.

**TABLE 14**

<table>
<thead>
<tr>
<th>Mercury concentration in mg/g</th>
<th>Place and number of samples taken</th>
<th>Demonstration table</th>
<th>Total samples taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastered walls</td>
<td>Plaster ceiling</td>
<td>Parquet and moldings</td>
<td>Student desks</td>
</tr>
<tr>
<td>Not recorded</td>
<td>11</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Traces</td>
<td>8</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>0.0001-0.0004</td>
<td>17</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>0.0005-0.0009</td>
<td>28</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>0.001 -0.004</td>
<td>2</td>
<td>12</td>
<td>37</td>
</tr>
<tr>
<td>0.005 -0.009</td>
<td>--</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td>0.01 and higher</td>
<td>6</td>
<td>--</td>
<td>44</td>
</tr>
</tbody>
</table>

Total samples taken: 72 | 68 | 120 | 28 | 54

The preceding data indicates the need for a chemistry and physics surveillance program emphasizing cataloging of equipment, and conducting experiments with an aim to precluding the possibility of mercury entering the air.

Mercury-containing instruments in schools are regulated by the official programs for preparatory schools. They conform with the decree "on strengthening the bonds between schools and life and of the further development of the national education system in the Soviet Union," which emphasizes the use of such equipment in classrooms. Currently, the secondary school syllabus requires
twenty-one demonstrations and laboratory work involving some mercury filled instruments. In class VI "properties of liquids", "properties of gases" -- in class VII "density and work", etc. Special decrees of the Council of Ministers RSFSR announce the list of typical academic equipment for general preparatory and school-intern programs. These devices are usually constructed of easily frangible glass which, if broken, can contaminate the hands of experimentors. Also operations with exposed mercury surfaces must necessarily contaminate the premises. Lists prepared by ministries of the republic are likely to expand the numbers and types of mercury apparatus in general use. It prescribes the storage of up to 0.5 kg of mercury, but schools as a rule store significantly more mercury. Thus we encountered up to 5 - 8 kg Hg in schools. In some schools the number of experiments using mercury instruments far exceeded the established minimum.

Despite the above described mercury demonstrations, in many cases schools do not adhere to safety requirements for the structure and sanitation of places where metallic mercury is employed.

Exhaust hoods, mechanical barriers, mercury-proof paints adhering to the SNIP structural norms were not observed in physics or chemistry classrooms, nor was there adequate ventilation in the prep rooms. This to a significant degree, contributed to the formation of sorbed mercury deposits, which later constitute the primary source of released vapor at the premises.

Often physics classrooms are moved to new locations without preliminary demercurization of general academic sites. Mercury can thus be seeded throughout the school, creating a number of secondary contamination sources. This "migration" can lead to massive contamination of the whole school building with mercury.

Occasionally the pedagogical. literature will carry articles dealing with problems of teaching physics in the schools. These articles mention the danger of mercury during its use in the physics and chemistry classroom. One of the teacher manuals stated categorically the need for safe conditions for handling mercury in the schools (Ye. N. Goryachkin, S. I. Ivanov, A. A. Pokrovskiy, 1940).

We conclude with the micromercurialism problem in schools as expressed by Professor Reynbolt, one of the experimental methodists on the technique of demonstrated experiments. "Manipulation of mercury as with water, is easy to visualize, is worthy of mention". Further, the necessity for strict observation of the rules of hygiene is expressed:

"...is vital to the health of our comrades, scholars and descendents."

(Cited in Ye. N. Goryachtskin, S. I. Ivanov, A. A. Pokrovskiy, 1940).

Thus, it is evident from the preceding data that the physics and chemistry classroom can be listed among the objects which can have harmful mercury vapor effects.

The effective prophylaxis of mercurialism in general preparatory schools is the general task of pedagogs and physicians.

Mercury in the Atmosphere

Data in this chapter showed that installations and facilities employing mercury under contemporary urban conditions are many and varied.

A significant question arises: must there be aerial mercury in the urban atmosphere in the absence of heavy industry utilizing significant amounts of mercury or its compounds? To answer this question we determined the mercury content in the atmosphere of Kiev and also in a "control region" situated 30 km from the city and 2 - 3 km from the nearest settled point (a farm community).

The sensitivity of the method and sampling conditions permitted the determination of minimal concentrations -- 0.0002 mg Hg/m3 in air.
Our data indicated no mercury in the air of the control region. At the same time, mercury appeared in the air samples from the city. Even in residential areas only 4 of 14 samples yielded almost negative results; the residual quantities of mercury varied between 0.0002 -- 0.00035 mg/m³. Higher concentrations (0.00025 -- 0.0005 mg/m³ occurred in the central region of the city.

In analyzing this data we compared our results with those of analogous investigations conducted by S. A. Davydov (kiev Scientific-Research Institute of General and Community Hygiene, 1951) to determine the content of sulfuric anhydride, hydrocarbons and soot. Residential areas in summer and winter had between 0.25 -- 0.048 mg/m³ SO₂ gas. The average hydrocarbon content varied between 156.3 -- 756.6 mg/m³ and the soot content from 25.4 -- 36.3%. In industrial regions, for example, in the Podol region, the content of the above substances varied within a higher, wider range. Thus, the sulfuric anhydride content in summer (according to averaged data) was 12 times higher in this region than in the central. Note that the aerial mercury content in industrial regions is not only significant, but more than 1.5 -- 2 times higher than at the center of the city (0.00053 -- 0.0010 mg/m³).

How is this position explained? What determines the aerial presence of mercury in the absence of specialized enterprises where it is produced or used in large quantities? In our opinion it is explained by the following reasons. First, the presence in industrial districts of a larger number of mercury vapor pollution sources than in central districts; second, the absence of any connection with purification operations discharging mercury into the atmosphere; and third, the possible entry into the air of small quantities of mercury with flue gasses, since mercury, as noted above, is present in small quantities in coal and fuels. The link between aerial mercury content and sulfuric anhydride, soot and hydrocarbon content has been demonstrated.

There has been interest in establishing data on mercury contamination of the air and soil in various districts of Kiev. There is a definite parallel between atmospheric and soil mercury content. Thus, the highest mercury concentration per 100 g soil (0.66 mg) occurred in industrial regions, significantly less in the center of the city, still less in a new housing development (trace amounts or none). No mercury was detected in soil samples taken far outside the city.

Therefore, under the conditions in a large city, where along with industries which can use mercury, there are many laboratories etc. using mercury and mercury instruments daily, there is about 0.00025 -- 0.00065 mg/m³ Hg in the air. These data conform to earlier results of the Moscow Institute of Sanitation and Hygiene imeni F.F. Erisman and the Institute of General and Community Hygiene AMN SSSR (R.G. Leytes, 1952). However, very high mercury concentrations (0.001 -- 0.004 mg/m³) were sometimes observed in the central city by the Erisinan Institute. Leytes concluded that the air of large cities has mercury contents varying between 0.0003 to 0.002 -- 0.003 mg/m³. The aerial concentration approaches 0.002 -- 0.003 mg/m³ conforming to our observations in and about industrial sites, some of which were engaged in instrument production. Truly, the presence of mercury in the air of these districts is produced by vacuum pumps and other mercury-containing devices. Laboratory vacuum pumps and apparatus can discharge up to 0.02 -- 0.06 mg Hg/min (1.55 -- 3.6 mg/hr).

The mercury content of the outlet of a type RVN-20 pump was about 2 - 3 mg Hg/liv, according to data of NIIOGAZA in its evaluation of mercury adsorption in pump outlets employed in fluorescent lamb production.

Mercury contaminates air of the urban industrial district much less when exhaust hoods are used in mercury operations, particularly those in which the metal is heated.
CHAPTER V
PROBLEMS OF SECONDARY CONTAMINATION BY MERCURY OF THE AIR OF PRODUCTION SITES

As previously noted the mercury air contamination at industrial sites has decreased from year to year and, in a majority of cases, varies within limits close to 0.01 mg/m³. Currently at certain industrial enterprises and in establishments using mercury or mercury containing Instruments, the last few years have seen a relative stabilization of the aerial mercury content.

In most cases this is apparently connected with secondary contamination of working premises by so-called fallow mercury absorbed into structural elements from the air.

The presence of secondary sources for the release of mercury into the air of the production site work zone or places of earlier mercury use was described by I. P. Nikonets, (1959). E. A. Goldman (1964), M. Z. Gofman (1963), M. N. Korshun, I. L. Kurinnyy, V. A. Zakordonets. V. V. Kirsenko (1965) and others.

Generalization of results obtained in analysis of specific cases of secondary mercury air contamination led to measures to liquidate the hazard of chronic mercury intoxication; investigations of the effectiveness of demercurizing chemicals have led today to a definite interest in this on the part of a wide circle of sanitation physicians.

We will describe a few cases of secondary mercury contamination discovered by us at a series of industrial sites and in establishments that make daily use of mercury, mercury salts, devices and apparatus containing mercury.

First case, a mercury instrument manufacturing plant surveyed in 1944. Many months of observation in a series of departments and shops making or using mercury filled instruments showed that mercury gradually migrated from one production site to another. (Figure 4). It penetrated first the production sites, then technical control from the metallic mercury storage area. It is sufficient to glance at the accompanying floor plan of the production premises to see where earlier use of mercury was followed by its movements into other parts of the building over the years, making the whole building a mercury exposure hazard.

Engraving shop workers (1) for example and personnel of the chief mechanic's shop (2) now occupy premises previously a storage area and then a glassblowing shop for two years. In the present galvanic department (3) was a storage area for finished devices in which were stored thermometers, manometers, parometers and other mercury filled instruments; the mechanical section (4) was formerly where the thermometers were filled with mercury. This same section of the building now houses a work site under the plant boiler (5). Both the first and second floors contained mercury shops and departments where mercury accumulated. This was especially so on the third floor. Here in the conference room (11), was a former glassblowing area and calibration shop which contaminated adjoining premises (12) with byproducts of the glassblowing shop. Later, part of the old glassblowing area was occupied by the present technical control section (13). Earlier, this spot was a storage area for finished items.

Thus our studies encompassed not only strictly isolated mercury operations but illustrated the place of migration of mercury throughout the entire building, as a consequence of operations which were connected with massive release of the contaminating vapor. At many sites there were intense foci of secondary mercury contamination of the air of the work zone. It was present in comparatively high concentrations in wall elements (0.0005 – 0.035 mg/g) and ceilings.
in the wood of window frames (0.0001 – 0.0007 mg/g), door (0.00015 – 0.015 mg/g), window sills (0.0005 – 0.025 mg/g), baseboards (0.00025 – 0.065 mg/g) and especially floors (0.001 – 0.08 mg/g) sites of prolonged desorption of mercury. These structural elements maintained a continuous supply of mercury at this place for several years. Despite the cessation of all mercury operations, the periodic demercurization of the site with potassium permanganate ferric chloride, the mechanical removal of mercury depots from the subflooring, its aerial concentration diminished little but continued at a relatively high level (0.01 – 0.03 mg/m³, average quantities). After specialized removal from the structural elements listed above the concentration began to diminish. However this diminution was not consistent in all sites. In one spot the mercury content fell to 0.01 mg/m³ and lower but this did not happen in a series of other places; in some sites primarily administrative, the amount of mercury began to rise again after a brief drop. Analysis of the reason for this re contamination (after removal of absorbed mercury foci from structural materials) revealed sufficient additional desorption sources. These included: old furniture, office inventory, and in a few production locations wooden parts of the working materials contaminated with mercury more than 6-7 years previously (Table 15).

Later in the course of specializes operations, mercury was detected in subfloorings between stories of the building (0.012 – 0.028 mg/g) and in cement floors of the basement (0.0025 – 0.040 mg/g).

Two conclusions were derived from analysis of this data. The first is that in cases of deep penetration of mercury into structural elements strong demercurization is not sufficient in repair work without special measures even in cases of the simultaneous removal of fallout mercury and treatment of the contaminated structure with demercurizing solutions. The second is the necessity of discovery and "dilution" of all possible secondary mercury contamination sources, including those which at first glance seem to be insignificant.

In the second case resulting from the absorption of mercury vapor by structural materials and equipment, mercury was found in most places in two buildings in which earlier there had been establishments, employing technical laboratory apparatus (control-monitoring devices filled with mercury frequently, differential manometers, type DP). Adjustment and repair of devices in this laboratory was linked to processes and operations involving exposed mercury (filtration, purification, filling instruments, etc.) which contaminated the air of the work site with mercury. In this particular case we did not know what the earlier concentration had been (the secondary contamination was noted 5 years after the laboratory moved). However the mercury content at these sites varied within broad limits – most often from 0.005 – 0.008 mg/m³ to 0.03 – 0.06 mg/m³, increasing depending upon the volume of mercury used, the character of the operation, instrument operation, instrument operation techniques, temperature conditions, etc. Naturally, in this case the aerial mercury concentration (in the operation period) reached a quantity exceeding 0.01 mg/m³ by 3 – 6 times. The continued presence of aerial mercury vapor was possible because of significant depots of absorbed mercury causing secondary contamination not only of the indicated premises but of neighboring sites and also, in the second case, of a separate building.

In industrial sites free of previous mercury operations mercury concentration did not exceed 0.0005 – 0.0015 mg/m³ in any structural element. At sites where there was earlier use of mercury filled instruments which left secondary mercury depots, the secondary mercury contents were: in "mercury" rooms, 0.01 – 0.03 mg/m³; in "packing" areas, 0.007 – 0.015 mg/m³; in utility buildings, 0.006 – 0.02 mg/m³; in a corridor, 0.0065 – 0.009 mg/m³; and in administrative and office locations, 0.01 – 0.025 mg/m³. The average mercury concentration in walls, ceilings, flooring and subfloorings was 0.0005 – 0.01 mg/g. Mercury was discovered in working and office furniture (0.00015 –
0.002 mg/g), in curtain material (0.0002 — 0.00055 mg/g). It is significant that subsequently mercury was observed in sites to which furnishings had been moved in connection with the first demercurization operation. Later, through migration, it penetrated to places where it should never have been.

Radical demercurization recommended by us should be thorough.

Secondary contamination of production premises as a result of mercury deposition in structural elements and subsequent prolonged desorption into the surrounding air was observed by us at an electric heat generating station. Our data shows that the second story, where there had been earlier use of mercury-filled instruments, was the site of a fallow mercury depot which released mercury vapor into the work zone, although mercury operations had ceased five years before. Repairs were going on at the site, in the course of which the structure of the building was treated with 20% ferric chloride solution. The presence of relatively high concentration, exceeding safe limits, occurred in the absence of "demercurizing" effect (in the case of secondary contamination) during general repairs even though treated with chemical demercurizers. Further studies established that there were significant mercury depots in all corners of the building and that radical measures were indicated (removal of secondary sources of aerial mercury). A series of laboratories engaged in mercury purification or differential manometer work moved instruments from one location to another. Thus secondary mercury "foci" were established by desorption from structural elements and furnishings.
Secondary mercury contamination is also well known in transformer stations, all types of scientific and technical laboratories, schools, dental offices, etc. Presently new materials and processes can release mercury into the air of factories, offices and even homes. The wide use of mercury lamps in plants have shown the need for special demercurizing procedures (E. I. Goi'dman, 1964). These cases point out that the industrial physician can encounter contamination in places where mercury has never been. Mercury devices for film processing are currently in use in Moscow, Kiev, L'vov, Chernigov and other cities and their use involves the release of mercury from exposed surfaces, after the action of electric current. Residue and droplets of mercury spatter and contaminate the premises (walls, floors, etc.). Further investigation revealed toxic concentration of mercury in cement floors (0.5 mg/g), walls (2 mg/g), pipes (0.4 - 2g/g), wooden structures (0.05 - 0.25 mg/g), in the air (0.02 - 0.03 mg/m3) and other structures (0.003 - 0.1 mg/g).

Other data as well as ours show that structural elements of buildings serve to maintain the circulation of mercury for prolonged periods (Figure 5).

The current specialized literature does not describe cases of domestic mercury contamination although it occurs.

From 1948 to 1951 we inspected the first and second stories of a Lugansk apartment house incorporating the so-called Gas Laboratory of the trust "Luganskuglegeologiya". Personnel of this laboratory used metallic mercury widely (as a degasser) in gas analysis. For years thereafter mercury smears were taken from the floors and ventilators of the building. According to laboratory personnel, several kilograms of mercury had been used, and significant quantities lost, during this period.

| Table 15 |
|------------------------|-----------------------------|------------------|
| Name of site           | Place where sample taken    | Average mercury content in mg/g |
| Engraving shop         | Work benches (wood)         | 0.004             |
|                        | Stools                      | 0.005             |
| Experimental production laboratory (rooms 1 and 2) | Wooden shelving | 0.4 |
|                        | Wooden benches             | 0.4               |
|                        | Individual lockers for protective clothing (wooden) | 0.06 |
|                        | Bookshelves (wooden)        | 0.04              |
|                        | Writing desks               | 0.055             |
| Bookkeeping dept.      | Writing paper stored in bookshelves and desks | 0.03 |
|                        | Cardboard cartons           | 0.05              |
|                        | Bookshelves (wooden)        | 0.002             |
| Technology division    | Drafting tables             | 0.0015            |
|                        | Writing desks               | not recorded      |
|                        | Writing desks               | not recorded      |
|                        | Bookshelves (wooden)        | 0.0015            |
|                        | Writing paper               | 0.0009            |
|                        | Stools                      | not recorded      |
|                        | Divans                      | 0.00055           |
|                        | Limonoleum on tables        | 0.001             |
|                        | Bookshelves (wooden)        | not recorded      |
The living quarters were in a four-story marl covered pre-war building divided into five sections and the laboratory occupied the first and second sections of the first floor. In 1951, after four years next to the apartments, the laboratory moved to another building and five apartments were made of the former laboratory site. Before tenants moved in there "had been extensive renovations" (repainting, replastering, floor finishing, repairs to sills, sashes, moldings, etc.).

**FIGURE 5**

Mercury Circulation in Working Premises

By the end of 1954, three years after opening the apartments, personnel of the sanitary-epideriological station analyzed samples collected there and found mercury (L. S. Perebeam, P. F. Tashchi, 1964). All air samples contained mercury vapor from 0.0025 - 0.006 mg/m³. The air of one apartment in the second section contained a maximum content of 0.0187 mg/m³. Simultaneous sampling analysis for mercury from the walls and ceilings showed that in all samples there was from 0.004 - 0.006 mg/g. In apartment 9, where the mercury concentration was highest, there was the highest wall content (up to 0.0042 mg/g).

Especially interesting is data on the presence of mercury in the plaster of apartments in which no earlier work with mercury had occurred. The fact that 83 of 99 locations were contaminated with mercury shows the significant secondary contamination of the whole building. The Lugansk Sanitary-Epidemiological Station showed that in 31 cases the mercury content in the plaster was about 0.000015 mg/g; in 47 cases, from 0.000015 - 0.00015 mg/g; in 5, above 0.00015 mg/g. Mercury was not detected in sixteen locations.

Conclusive secondary mercury contamination was arhown by analysis of wall samples taken two years after the plaster samples from depths of two to five cm and then at eight cm. The average mercury content in these materials was 0.000004 - 0.000034 mg/g; at 2 and 5 cm, 0.000014 - 0.000013 mg/g. The mercury content of walls and plaster diminished in a direction from the first to the second section, where the laboratory had been, to the fifth section where mercury was not detected in wall material.

Control analysis of 45 composition marl wall material samples showed no mercury. This confirmed the contamination of the building.
by the laboratory.

The possibility of contamination of apartments colocated with dental offices in a building was described by I. D. Krupitskaya and I. L. Pisarevskiy (1956), illustrating the dangers of use of even insignificant quantities of mercury.

Attempts at demercurization and installation of mercury barriers were not effective because of mercury penetration deep into structural members. M. N. Korshyn, at an instrument building plant, confirmed these observations. Less than two years of shop operation, even with recommended mercury barriers, produced massive mercury contamination of structural elements of the building. The mercury content of an asphalt linoleum-covered cement floor was an average of 0.001 - 0.002 mg/g, varying within limits of 0.0005 - 0.4 mg/g; wall plaster covered with a recommended oil base paint (No. 81/8 - 7) contained an average of 0.0002 - 0.01 mg/g. average 0.002 - 0.003 mg/g. Contamination was highest in plaster, then in wood and least in cement floors. Special wall paints and plaster were more permeable to mercury than linoleum. Cement was more porous than plaster.

Recently multiple problems of secondary mercury contamination were addressed at the Department of Industrial Hygiene of the Kiev Medical Institute (M. N. Korshum, 1965 - 1967). These studies showed that the mercury content of structural components determined the aerial mercury content. This is important from a hygienic point of view in that a mercury content exceeding 0.0003 mg/m3 by 3 - 4 times can deposit onto structural elements, which contain the largest amount of mercury in comparison with total background depot levels.

The greatest influence on the quantity of deposited mercury is exerted by the system of "protected" structuring. The use of such "protective" coatings significantly decreases the intensity of secondary sources. Thus, under an asphalt based coating, there is 15 - 80 times less mercury than in unprotected plaster. An important indicator of the strength of a secondary mercury deposit is its depth of penetration (A. S. Arkhipov, et al, 1950; M. N. Korshun, 1967); indicating the growing volume of demercurization problems. Mercury can penetrate plaster to a depth of 10 - 15 cm. The diffusion of mercury through walls is determined by their plaster content.

As the mercury penetration decreases, so does the number of positive tests and the quantities observed therein.

M. N. Korshun showed that secondary depots could maintain aerial mercury vapor levels of up to 0.05 - 0.07 mg/m3.

Secondary mercury sources determine its vapor persistance in the air of many production establishments and laboratories even where mercury droplets have been removed by demercurization measures.

In a chemical viscose production site mercury was detected in the air for three months despite complete removal of the primary mercury source.

In industrial laboratory studies, it was shown that the aerial mercury concentration (in mg/m3) is one order higher than the mercury content in structural elements (in mg/g).

This relationship is used in classifying mercury deposit sources. Thus, there are three degrees of contamination; primary (insignificant intensity) - mercury content on the order of ten thousandths of a mg/g; secondary (average intensity) - thousandths of a mg/g, tertiary (high intensity) - hundredths mg/g and higher.

Depending on the presence of mercury supporting structures can be a massive contamination source spreading the contamination through internal elements, conduits, foundations, etc., and also can be surface contamination sources, accumulating mercury on walls, floors, etc.
This classification can differentiate the type of demercurizing measures on the basis of source and site utilization characteristics.

The hygienic significance of such depots is based not only on hygienic investigations, but on data of medical surveys of persons who had no direct mercury contact but who had spent long periods in mercury contaminated sites.

Fifty seven percent of persons studied displayed functional CNS disturbance of the asthenic type, asthenovegetative syndrome and vegetative-vascular dystonia. "Mercury erethism" appeared, changes in olfactory sensitivity, hematological shifts and increased urinary mercury contents, indicative of micromercurialism, connected with primary aerial mercury contamination were noted.

"Tertiary level sources" can be generated from spillage and absorption, although primary contamination plays its role. Secondary sources are the determining factor in contamination of new objects and sites in the laboratory and in industry and explain mercury level maintenance and circulation between the air and objects at a site.

THE MICROMERCURIALISM PHENOMENON IN MERCURY HANDLERS

The phenomenon and clinical aspects of common mercurialism are well known; the symptomatics of micromercurialism, caused by small mercury concentrations (hundredths of a mg/m3) are insufficiently defined. Further study, toxicological experimentation and clinical observations are needed.

Analysis of symptomatic complexes characterizing relative toxic effects deepen not only our understanding of the phenomenon and its pathology but permits more successful early diagnosis. In occupational pathology the early diagnosis problem is distinct from its general, clinical prophylactic significance. One must agree with N. A. Vigdorchik (1940) who said that the early diagnosis of an occupational pathology "is a timely danger signal, and a timely signal is the basis of effective prophylaxis."

A. Stock (1926) first described micromercurialism and noted especially changes in psychic function. He characterized micromercurialism symptoms in three groups according to degree of intensity of the phenomenon.

According to A. Stock, first degree micromercurialism results in lowered working capacity, increased fatigue, light nervous excitability. Often in the second degree there is swelling of the nasal membranes, progressive weakening of memory, feelings of fear and loss of self-confidence, irritability, headaches. Simultaneously there may be catarrhal symptoms and upper respiratory discomfort, changes in the mucous membranes of the mouth, bleeding gums. Sometimes there are feelings of coronary insufficiency, shivering, quickening pulse, and a tendency toward diarrhea. Third degree micromercurialism is characterized by symptoms approaching those of regular mercurialism, but to a lesser degree. The basic symptoms of this stage are: headaches, general weakness, sleep-lessness, decline in intellectual capacity, depression. Among other signs are tears, diarrhea, frequent urination, a feeling of pressure in the cardiac region, and shivering.

The diagnosis of micromercurialism in some cases is quite difficult.

M. P. Minker (1927) at the XV Scientific Conference of the Leningrad Institute for the Study of Occupational Diseases said that most cases of micromercurialism appear as an ailment of the respiratory or nervous system, depending on what predominates in the clinical picture.

A. M. Gel'fand (1928) also noted that "sometimes mercury poisoning in patients is mistaken for other diseases."
A. N. L'vov (1939) cited cases of micromercurialism misdiagnosed as neurasthenia, hysteria, etc. He notes that among mercury industry workers in three years there were only a few cases of chronic industry poisoning reported, while qualified pathologists frequently reported the phenomenon of micromercurialism among workers.

A most interesting study by this institute involved workers having continuous exposure to small concentrations of mercury vapor.

This chronic poisoning by small mercury concentrations is reflected in the total functional-neurotic condition, CNS effects and in cardiovascular activity. Ya. Z. Matusevich and L. M. Frumina (1934), investigated worker neuroses acquired after the prolonged action of small mercury concentrations which caused functional disturbances in the vegetative nervous system.

In surveying the symptoms of chronic mercury poisoning, we note its primary destructive effect on the subcortical ganglia. Much evidence of higher nervous and functional disturbances are in the works of N. M. Gimadeyev, 1958; E. A. Drogichina, L. G. Akhnyanskaya, D. A. Ginzberg, et. al., 1954; V. N. Kurnosov, 1962; H. N. Sadchikova, 1954.

Functional changes in the internal organs, especially the heart, in micromercurialism have been described by A. A. Oriova, 1954; liver and kidney disturbances, Kh. Z. Lyubetskiy, 1953; effects on endocrine organs, especially the thyroid gland, R. N. Vol'fovskaia, 1928; H. A. Kazakevich, 1933; A. M. Manayenkova, 1957.

A clinical-statistical study was made of 656 persons in contact with low mercury concentrations. Eighty-five of them were in-patients and the rest, out-patients. The results are shown in Table 16.

Age distribution of the subjects is shown in Table 17.

The tables show that most of these persons were between 20 and 29 years old. A small group (13 men, 23 women) were under 20 years old. Data on duration of exposure is shown in Table 18. The earliest symptoms of micromercurialism occurred in the persons most sensitive to toxic effects in the first year of contact. In observations of Ya. Z. Matusevich and L. M. Frumina (1934) these were different from later positive results.

The subjects could then be divided into three groups.

First -- workers in industrial enterprises having continuous or intermittent contact with low mercury concentrations as a consequence of their production activity. To this group belong glass- blowers, repair and calibration personnel, instrument makers, electrolysis workers (use of mercury cathodes) and instrument assembly workers.

The second group is composed of medical-biological employees and dental personnel having periodic contact with mercury vapor in the work zone.

The third group includes persons not in direct contact with mercury, but exposed to mercury vapor via secondary sources, (office workers, supervisors, etc. at places where 0.01 mg/m³ or lower have been recorded).

Such differentiation, permits an explanation of micromercurial- alism not only among persons occupationally exposed to mercury, but among those subjected to secondary exposure through occupation of previously contaminated sites.

Most of the above subjects were apparently healthy, although many of them presented a series of complaints. Most of these were subjective symptoms reflecting feelings of weakness. To a greater or lesser extent there were complaints of mercury impairment, insomnia and emotional disturbance. Also included were apathy, crying, daytime sleepiness with nightly insomnia and often a progressive decline in work capacity. These complaints were repeated from year to year in many of the subjects, however non-specific complaints predominated.
These were separated by symptomless periods -- the first feature of the initial appearance of micromercurialism.

**TABLE 16**

<table>
<thead>
<tr>
<th>Group of persons studied</th>
<th>Mercury concentration in mg/m³</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimal</td>
<td>Maximal</td>
</tr>
<tr>
<td>Workers at the KIP Plant</td>
<td>0.004-0.08</td>
<td>0.015-0.12</td>
</tr>
<tr>
<td>Personnel at scientific research institutes</td>
<td>Traces-0.01</td>
<td>0.055-0.08</td>
</tr>
<tr>
<td>Personnel of university departments</td>
<td>0.07 -0.15</td>
<td>0.01 -0.1</td>
</tr>
<tr>
<td>Transformer station personnel</td>
<td>0.007-0.01</td>
<td>0.01 -0.065</td>
</tr>
<tr>
<td>Medical personnel</td>
<td>Traces-0.025</td>
<td>0.015-0.17</td>
</tr>
<tr>
<td>Workers, engineers and technicians at various industrial enterprises and installations</td>
<td>0.0085-0.012</td>
<td>0.04 -0.15</td>
</tr>
</tbody>
</table>

**TABLE 17**

<table>
<thead>
<tr>
<th>Age</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 20</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>20 - 29</td>
<td>85</td>
<td>84</td>
</tr>
<tr>
<td>30 - 39</td>
<td>65</td>
<td>64</td>
</tr>
<tr>
<td>40 - 49</td>
<td>51</td>
<td>65</td>
</tr>
<tr>
<td>50 years and older</td>
<td>54</td>
<td>61</td>
</tr>
<tr>
<td>Total number of subjects</td>
<td>268</td>
<td>306</td>
</tr>
</tbody>
</table>

**TABLE 18**

**DATA ON THE PROFESSIONAL STATUS OF PERSONS HAVING CONTACT WITH LOW MERCURY CONCENTRATIONS**

<table>
<thead>
<tr>
<th>Employment Status</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than one year</td>
<td>24</td>
<td>38</td>
</tr>
<tr>
<td>1 - 4 years</td>
<td>109</td>
<td>121</td>
</tr>
<tr>
<td>5 - 9 years</td>
<td>51</td>
<td>69</td>
</tr>
<tr>
<td>10 and more years</td>
<td>84</td>
<td>78</td>
</tr>
<tr>
<td>Total number of subjects</td>
<td>268</td>
<td>306</td>
</tr>
</tbody>
</table>

*Workers at the KIP Plant are included in this table on the basis of their stay at the plant which usually determines their length of exposure to mercury.*
This feature establishes the "mercury" etiology and serves to differentiate the above complaints from analogous symptoms appearing as a consequence of general somatic diseases.

The second feature -- the presence of complaints during the entire period of mercury contact. We tried to determine the exposure time required to produce the first subjective signs of a mercury effect and how the first symptoms later develop into micromercurialism. This includes waiting for the first complaints, recording symptoms of developing neurasthenia. Of 144 persons in this group who displayed astheno-vegetative symptoms, the indicated signs appeared most often in the first six months of contact with mercury, and especially in the first year -- in six persons, in the second -- in 27, in the third -- in 12, in the fourth -- 14, in the fifth -- in 15, in the sixth -- in 18, in succeeding years -- in the rest (45 persons). Ninety-two of 137 persons had symptoms during the first - sixth years of working with mercury. In seven cases, micromercurialism symptoms were detected after ten years of work with mercury. In order to establish the presence or absence of phenomena of specific etiology, special attention was paid to data on anamnesis and also to a series of special observations (olfactometry, Teleky's symptom, uptake of radioactive iodine by the thyroid gland, etc.).

The data shows that asthenia appearing as a consequence of general somatic illness is very like that of "mercury" etiology, but differ in analogous subjective symptoms. In the first instance complaints of emotional malaise are usually absent; in the second, they dominate over the rest and, as a rule, are characterized by an increase in general irritability and sensitivity, annoyance, rapid mood changes, apathy, tendency towards crying.

Naturally, we qualify this syndrome as having a mercury etiology not only because of such complaints but as a result of detecting such objective signs as tremors, enlargement of the thyroid gland and its increased uptake of radioactive iodine, stable and increasing (under the influence of unithiol) excretion of mercury in the urine, etc. An important aid in establishing the occupational etiology are hematological shifts, comparison of their dynamics and the development time from onset of other (subjective and objective) symptoms of mercury effects.

At first glance it appears that the asthenic-vegetative syndrome occurs more often in women. However, statistical treatment of the obtained data indicate that it occurs equally frequently among men and women. Thus, there is no evidence of "lesser resistance" among women to mercury intoxication, although this is the conclusion of O. A. Gli-gorova, Ya. Z. Matusevich and L. M. Frumina (1934).

Analysis of the frequency of the asthenic-vegetative syndrome as related to age showed that, in both groups, it occurred more often in persons over forty. Data, characterizing this relationship is presented in Table 19.

This table shows the limits of variation of the obtained indicators in both groups (up to four years experience, 25.57 -- 43.63%, over five years, 31.25 - 49.96%) and that the frequency difference of the asthenic-vegetative syndrome as a function of work experience length is not reliable.

The absence of a true relationship between the frequency of this syndrome on the one hand, and the age composition of the workers on the other, confirms earlier data on anamnesia studies about the first signs of micromercurialism even in the first years of mercury exposure.

Our data analysis indicates that the effect of low mercury concentrations on workers' systems seems to invalidate concepts of age and work experience as factors. This does not mean that these factors cannot, in some cases, increase the intensity of the toxic effect and be a determining factor in the frequency and development of the micromercurialism phenomenon.

The asthenic-vegetative syndrome of "mercury" etiology differs from the analogous symptomatic complex of somatic illness in its manifestation of
emotional sensitivity which takes on the relatively stable character of micromercurialism.

Among these, first of all, are neurological symptoms, usually digital tremors of the extended hand. These tremors are usually intermittent in nature, appearing, as a rule only during agitation.

Among the neurological phenomena neuralgia and radiculitis, neuritis connected with the appearance of asthenia appears three times as often in "mercury" groups as in groups where this complex is absent. Neurological symptoms seldom occur up to age 39 and more often among older people. Note that a group of neurological symptoms not included are a series of vegetative shifts, such as tendency to tachycardia, pulse lability, cardio-vascular fluctuations, etc.

There are also such symptoms as red dermographism, increased tendency towards perspiration, etc. These shifts correspond to changes in certain endocrine functions, especially of the thyroid gland, which will be discussed below. An enlarged thyroid was noted in the first group in 55, and in the second in 18 persons. Thyroid dysfunction occurred in both groups up to age 29. A significant number occurred in those who had not been employed very long (from 1 - 4 years).

Analysis of the data make it impossible to ignore the high percentage of cases of functional disorders of the cardio-vascular system, liver, digestive tract, and changes in the mucosa of the mouth. There are complaints of chest pains or "colic," heart palpitations and a "sinking" heart in both groups, 29% in the first and 36% in the second. In an objective study of cardiovascular lability, vascular dystonia occurred in 34 and 39% of cases respectively. Especially interesting is data on cases of hypotonia (33% of persons in the first group and 31% in the second). Simultaneously, an increased arterial pressure (7 and 12% of cases) was noted. The majority of the subjects who had cardiovascular problems were over forty, but there was a large number of such cases among the 20 - 29 year-old group. Generally this symptom was directly related to length of contact with mercury.

Next in specific importance are functional shifts in the liver (first group 16%, second group 27% of cases). Note the number of persons 30 - 49 years in the first group and above fifty years in the second. Stomach and intestinal disturbances generally were accompanied by substernal pains, lowered appetite, a feeling of pressure under the sternum, nausea and vomiting in 11 and 25% of cases respectively. This symptomatic complex is like the picture of secretory neurosis of the stomach.

Some persons in contact with small amounts of mercury have many complaints about the mouth lining, (a metallic taste in the mouth, bleeding gums, increased
detachment of the lining). Some cases involve hyperemia of the mucosa and others mercury in the edges.

Mouth changes, shown to be of occupational etiology make up 10.3 and 21% of cases respectively. Indicatively, of 77 persons having these shifts, 69 also had an asthenic-neurotic syndrome of etiology.

In the third group (the smallest - 68 persons) more than half were 40 - 50 years and older. The length of employment of over half of these persons in mercury contaminated places was five to ten years and more. A feature of this contingent was, first, an absence of direct (caused by specific occupation) contact with mercury, second, predominance of older people. Thirty-five persons had subjective neurological symptoms, in 22 objective nervous system changes, particularly vegetative. Almost half (32 persons) manifested an asthenic-neurotic syndrome, which in 27, was of mercury etiology. Indicatively, functional disturbance of the cardiovascular system which appeared in 19 persons, liver changes in 14, stomatitis in 11, were observed in persons with an asthenic-neurotic syndrome of mercury etiology. An enlarged thyroid appeared in three persons, decreased arterial pressure in fifteen, increased pressure in six.

A comparison of this data with that of other authors (Ya. Z. Matushevich, I. L. Frumina, 1954) shows that in modern mercury use, where at the respiratory zone, the concentration it at or near the permissible limit (0.01 mg/m3) or at even lower levels, the effect is of a more latent or minimally symptomatic character than described earlier. The frequency of subjective and objective symptoms in persons contacting low mercury levels has decreased under modern conditions. However, this decrease is far from that deemed desirable for significant contingents in contact with mercury.

The data suggests a high number of "specific" functional shifts and disturbances and a general "nonspecific" syndrome of the initial and later phenomenon of micromercurialism. Our studies of workers in Kiev establishments have universal application. We will speak of workers in a Moscow enterprise, a shop of which, over a twelve year period had a mercury level from 0.006 - 0.04 mg/m3. This enterprise of the electrovacuum industry, possessed not only possibilities of direct mercury contact, but of mercury effects arising from technical processes involving low mercury concentrations and high surrounding air temperatures. This feature of the industry was described by us with I. V. Savitskiy and R. Ya. Shterngarts (1965) in which they stressed the absence, in earlier published works, of the treatment of the problems of micromercurialism, of such surveys of a contingent of persons subjected to the effect of small mercury concentrations on a background of high air temperature. As we have already stressed, such a combination prevails not only in the electrovacuum industry, but in metallurgical, electronic and chemical plants, etc.

In the study previously discussed, the first group worked under industrial conditions where the aerial mercury concentration was 0.01 - 0.05 mg/m3, the winter temperature, 16 - 24°C, and the Burner temperature 26 - 31°C, In the second group were persons having contact with 0.001 - 0.01 mg/m3 at temperatures of 28 - 38°C in the winter and 40-42°C in the summer. The control group was one having no contact with mercury but working at high temperatures (38 - 42°C).

Observational analysis of these groups indicates that the symptom complex is of occupational origin.

Comparative symptomatic frequencies between the two groups showed more complaints in the first group, while there were more objective symptoms (tremors, enlarged thyroid, etc.) in the second group. The differences can be attributed to the effects of high temperatures on the workers.

Thus the materials presented above signify micromercurialism in the subjects as a consequence of prolonged exposure to mercury in concentrations close to 0.01 mg/m3.
It is instructive to compare these results with those from observations of control group persons. The number and frequency of complaints and of objective deteriorations was 2.5 - 3 times rarer than in the basic group. Only 13.4% of the controls complained of insomnia, sweating and emotional sensitivity at the same time this incidence in the first and second group was 28.0 - 50.0% respectively. Tremors of the hands and eyelids and thyroid enlargement occurred in 8 12% of controls, and in the basic groups 28 and 37%.

The above materials on medical surveillance of persons in "mercury" occupations for the last seven years at the Moscow Electric Lamp Factory are even more argumentative from the point of view of conclusions generated and linked with clinical and statistical materials on worker studies at the same site worked out by E. I. Gol'man (1964). All data embraces the twelve-year period of the subjects and is quite conclusive.

Data obtained during this period on the time required for the first symptoms of mercury effect to appear conforms to other data above; 120 of 140 persons studied experienced different asthenic-vegetative complaints and symptoms determined to be initial signs of mercury effect. These symptoms appeared during the first five years of employment. In particular in the first year, it occurred in 77 persons, in the second, in 30, in the third, in 13 and in the fourth and fifth, in 4. Increased appearance of a mercury effect is observed in the third year after beginning work with mercury. According to E. I. Gol'dman, 36.3% of his subjects displayed early symptoms of micromercurialism after one year's employment, 77% after two years, and 15% after three years. Thus the tell-tale signs have usually appeared by the second year of exposure to mercury. Although most persons have displayed symptoms by the sixth year of mercury contact, in some cases ten or more years were required.

We investigated the distribution frequency of vascular hypotonia among persons in contact with low mercury concentrations. We found that, among the first group, the incidence was 33%, and in the second group 31%, which conforms to the data of E. I. Gol'dman (1964). We encountered increased arterial pressure more often than E.I. Gol'dman did. We did not notice such a difference in frequency of the latter in persons with the asthenic-vegetative syndrome in comparison with the rest of the subjects. We found vascular hypertonia to be absent among luminescent lamp workers having the most contact with metallic mercury, although 15% of this group were over 40.

Among these persons a significant percentage were exposed to both mercury vapor and high air temperatures. This group consisted of 122 persons: 69 men and 53 women. The majority were between 30 -39 years (81 persons). Most had been working with mercury for 5 - 10 years (92 persons).

Sixty-three persons (56.2% of the group) were diagnosed as having an asthenic-vegetative syndrome of mercury etiology and forty persons (35.6% of cases) had low blood pressure. Six persons (5.3%) had increased arterial pressure. In recent years there has been a decrease in the number of persons with arterial hypertension. S.D. Reyzel'man found lowered blood pressure in a group of mercury workers in 50% of the men and 68% of the women. R. N. Vol'fovskaya found hypertension among 42% of surveyed persons in "mercury" occupations. According to other data the total number of cases was 60% of all subjects studied, or 44.4% (I. M. Livshits). Ya. Z. Matusevich and L. M. Frumina found hypertension in 50% of the men and 68% of the women.

In looking at results of hematological studies we note that the number of subjects with less than 70% hemoglobin increases with length of work with mercury. Thus, after one year of employment, decreased hemoglobin occurred in 29.8% of cases and among persons employed ten years or more, it occurred in 40.59% (Figure 6).
Analysis of erythrocyte counts showed that, with increasing length of employment (one to ten years), the number of persons with less than 3,500,000/mm³ increased almost two-fold (from 14.49% to 26.73%). At the same time there was a five-fold decrease in the number of patients with counts of over 4,500,000 (from 36.17% to 7.92%) (Figure 7).

Among persons with the astheno-neurotic syndrome, showing signs of a "mercury" etiology, the number of subjects in whom hemoglobin was less than 70% was 40.14%, and the number who had less than 5,000,000 erythrocytes was 27.73% of the total.

Along with the hemoglobin studies we determined the bilirubin content of the blood and found it above "normal" (0.6 - 1.2 mg%) in a significant number of cases (48.9%) of persons having contact with mercury. A higher percent (57.59%) was found in the group having an astheno-neurotic syndrome of occupational (mercury) etiology.

There was an increased reticulocyte level in the blood of persons with asthenic-vegetative syndromes (10.28%). Interestingly, this percentage decreases with length of employment. Thus, among persons with four years or less experience, the reticulocyte level was up in 31.02%, and in persons with ten or more years experience, in 8.14%.
The white cell count in these subjects was below 6,000. With increasing length of experience, there was an increase in the number of persons with a decreased leucocyte count (from 15.53 to 55.44%), and the number of persons with a count higher than 8,000 fell threefold (from 46.8 to 14.85%). Lymphocytosis occurred in 19.89% of cases. Eosinophilia (over 5% eosinophils) occurred in 12.5% of cases, and eosinophilopenia -- in 14.6%. Eosinophilopenia decreases from 27.6% to 0.

There is a slow development over the years of hypochromic anemia with the presence of hemolysis leading to increased bilirubin in the blood (indirect reaction). Granularity of erythrocytes increased in 29% of cases and corresponds with increased regenerative activity of the bone marrow. On the other hand, the decrease in the number of persons with increased reticulocyte contents, the increase in leukopenia, the growth of eosinophilopenia and the absence of nuclear shifts in leucocytes increases with length of employment, and the prolonged effect of low concentrations is a gradual inhibition of the hematopoetic function of the bone marrow.
Materials characterizing the urinary mercury content were analyzed. In our laboratory 637 analyses for mercury associated with low external concentrations were done in five years, using a method worked out by S. L. Ginzburg (1948). In time, certain parts of the method were improved significantly and a standard solution was used (iodine and potassium iodide containing 0.001 mg Hg/ml).

The majority of urinary mercury levels is independent of length of subject contact with mercury. In some cases no urinary mercury was detected. The unithiol uptake was followed (0.5 gm twice a day). There was later increased urinary mercury content only in cases where mercury had previously been found in the urine and is connected with increased release of mercury from the depot under the influence of unithiol. Other studies confirmed the release of mercury under the influence of unithiol administered prophylactically or diagnostically (S. I. Ashbel' and V. A. Tret'yakova, 1958; A. A. Model', 1959; G. A. Belonozhko, 1959, et al). It must be stressed that when unithiol (in some persons) suddenly increased the urinary mercury output, there was a short term decline in general well being. As a rule patients complained of powerful headaches, appearance of a metallic taste in the mouth, progressive decline in working ability and increase in general weakness. S. I. Ashbel' and V. A. Tret'yakova observed this decline in general well being after "strong mobilization of mercury compounds from the depots" as we observed it in patients with the asthenic-neurotic syndrome in the absence of visible toxic damage. In all subjects mercury was not excreted regularly; sharp increases were followed by drops to the levels of healthy persons who had no contact with mercury.

Persons having contact with low mercury concentrations excrete mercury in quantities on the order of thousandths, hundredths or tenths of a mg/l. Therefore there is no correlation between the amount excreted in the urine and the presence of subjective or objective symptoms. This data does not justify a correlation between the urinary mercury content and length of contact with mercury.

Our data suggests that mercury is taken into the body, circulates in it for a long time, and is only slowly excreted.

The elimination of mercury often increases under harmful stress such as lowering of the general reactivity of the body, when there is a release of mercury from the depot and its circulation in the blood. For example, during an influenza outbreak in 1959 mercury was detected in the urine of workers in a transformer station. Most of these persons suffered from influenza and their urinary mercury output rose sharply.

Our data also shows that there is increased urinary mercury output under the influence of unithiol. This is usually detected in cases where the micromercurialism is of a latent character and the analysis of the asthenic-vegetative syndrome is not "specific" for a mercury etiology.

Studies of olfactory sensitivity have been made by A. Z. Dubrovskiy (1954), in which olfactometers measured odor intensity during the investigation. His olfactometer made it possible to study the degree of olfactory and trigeminal sensitivity of smell in response of the release of peppermint oil droplets of 30% acetic acid solutions.

The determinations of olfactory sensitivity used a 170 person control group taken from the experimental group made up of employees of the KIF, 67 persons, departmental personnel of polytechnic institutes and the Institute of Hydrology and Hydrotechnology AN UkrSSR, and also 92 persons who had spent a long time in places contaminated by earlier mercury use.

The results showed that olfactory sensitivities in both groups corresponded. Sensitivity shifts depended on how long a subject had been accustomed to the industrial premises. Threshold sensitivity was highest in persons who had been exposed to mercury contaminated sites for a long time (40 - 45 units of tonometric pressure; The first number refers to olfactory stimulation; the second to trigeminal).
Besides threshold sensitivity he studied adaptation to odor at threshold concentration and the recovery time after olfactory loading by vapor of a volatile substance. Negative responses were taken every five seconds and the number of negatives studied at 60 - 120 seconds. The adaptation time to peppermint oil was low. After ten seconds 54 persons had adapted to this odor at the same time that 36 persons in the control group required 30 seconds. In two minutes 83 persons in the experimental group had adapted while only 68 of the control group had done so. Analogous results were obtained with acetic acid.

A third indicator, characterizing the recovery of olfactory sensation at the threshold quantity, was noted in 37 cases of the experimental group within 30 seconds and within two minutes in 69; while in the control group the time corresponded in 72 and 92 cases. There was hyperosmia in 12 persons (21%).

With adaptation time shortened, less time was required for responses. In the healthy group, the time varied within wide limits - 30 to 45 seconds - 30 minutes (average for peppermint 1.5 - 2.4 minutes and for acetic acid 1.1 - 2.0 minutes). In the mercury group adaptation time was much shorter (8 to 10 seconds - 2 minutes). Recovery of olfactory sensitivity under load required 30 - 100 seconds for the control group and 45 - 146 seconds for the mercury group. In the other cases threshold sensitivity was 60 - 80 units and the recovery time 7 - 10 minutes and longer. This occurred in cases of recorded micromercurialism. However, some cases (17%) with high olfactory sensitivity showed a tendency toward increased adaptation time and shortened recovery time (of threshold sensitivity) after olfactory load. Generally in these persons mercury effects were absent.

Analogous data was obtained for the KIP plant, and academic and industrial laboratories.

Thus, analysis of olfactometric indicators in subjects correspond to a biphasic mercury effect on the olfactory analyzor. The first phase is the decrease in threshold sensitivity, and speeding up on the recovery period after load. The second phase is increased threshold sensitivity and a prolonged recovery time. In the first phase, in cases where other functional shifts have been recorded frequently in the thyroid gland, a series of vegetative indicators, especially in liver function, a depression in threshold sensitivity under repeated stress is noted.

In persons having contact with low mercury concentrations (primarily with the appearance of the astheno-vegetative syndrome) we studied the functional state of the thyroid gland. Some of these people worked at the KIP plant. Among them were 36 men and 31 women. Their ages, between 30--45 years (43 persons), over 45 (24 persons). They had worked with mercury for 5 - 10 years.

Results are shown in Table 20, differentiated on the basis of radioactive iodine uptake by the thyroid. The characterizations were as follows: less than 10% uptake, below normal; 10.1 - 15%, low borderline normal; 15.1 - 25%, average; 25.1 - 30% high borderline normal; above 30%, increased functional activity.

As is evident from the table there are definite variations in the determined quantities among the subjects. Thus, in the control group as among the men and women there were persons in whom (24 of 45) the uptake of radioactive iodine was normal. Some subjects studied were generally above normal but there were five persons whose thyroids took up more than 30% of the radioactive iodine. A different character is seen in the profile of persons having contact with mercury. Among these there is a definite tendency toward increased thyroid activity at the high normal borderline. Indicatively, persons with low and average uptake made up 33% of the group (23 of 67 persons). Not only after 24 hours from the moment the isotope was administered, but also during the 2 hour investigation, the percent uptake of radioactive iodine by the thyroid gland in this group exceeded the norm in many cases (in conformity with the literature data, the normal thyroid uptake after 2 hours is 5 - 9%). There is a tendency toward an increase in this with an increase in exposure: to 6 - 8 hours. In almost all cases (61 of 67), the maximum uptake is noted within 24 hours from
the administration of the isotope. Note that in this period 5 of the persons had
an uptake rate below 10%.

**TABLE 20**

| Absorption characteristics for 1 | Group Studied | Control Group |
|---------------------------------|--------------|---------------|---------------|
| Below normal                    | 2             | 3             | 5             | 1             | 2             | 3             |
| Low borderline                  | 1             | --            | 1             | 4             | 4             | 8             |
| Average                         | 5             | 6             | 17            | 17            | 7             | 24            |
| High borderline                 | 17            | 10            | 2             | 2             | 3             | 5             |
| Excessive activity (more than 30% radioactive uptake) | 17 | 12 | 2 | 2 | 3 | 5 |

Statistical treatment of this data indicates the reliability of the quantities. Thus, in comparing results taken twenty-four hours after administration of the isotope, in a group of men with more than eight years experience (ages from 30 - 45) the average uptake and margin of error was 32.17 + 2.24, at the time that of an analogous group was 20.8 + 2.6.

In cases where the asthenic-vegetative syndrome is present, thyroid activity is increased, the objective signs include red dermographism, finger tremors in the extended hand, sweating and, in a number of persons, enlarged glands.

Radioactive iodine uptake by the thyroid gland under even low quantities of mercury can increase significantly. Persons who show increased uptake of the isotope, as a rule, show symptoms indicating glandular dysfunction; enlargement, finger tremors, emotional sensitivity, etc. This conclusion agrees with the observations of A. M. Monayenkova, M. N. Ryzhkova, and M. I. Smirnova (1959).

Small quantities of mercury effect the so-called Teleky Symptom (B.B. Koyranskiy, 1930; B. B. Koyranskiy and Ye. Ya. Benediktov, 1931) although this is questioned by others (N. A. Vigdorchik, 1927, 1928; I. G. Gel'man, 1935). The reason for this controversy is the difference and insufficiency in the methods used by the authors in determining data.

Therefore we devised a method, differing from previous ones using a special device based on the Kollen dynamometer and designed to test the strength of extension.

The device has a scale, indicating in kilograms the strength of a muscle compressing a piston. Thus there is direct registration of results on the scale. The construction of the device permits measurement of the angle of the wrist. (Figure 8).

The measurement proceeds as follows: the subject rests his right hand in the special holder running along the location of the forearm and hand. Then the forearm and hand are lightly fixed as shown, the wrist freely makes a right angle.

Fixed thus, the subject slowly extends the wrist flexing the plastic which pulls the piston. An arrow indicates the results on a scale. Then the right hand is freed and the left fastened and the procedure repeated.
In working out the recommended method (and in the construction of the device used in the experiments) we tried to remove insufficiencies found in previous methods. First, muscle power is measured at the maximum drawing out of the piston. Second, our results are not indirect data derived from units of work for "comparison" with unit strengths, but are absolute indicators. Third, the device is constructed so that the transmission of movement is not lost in intermediate movements lowering the accuracy of the results: there is direct transmission of wrist movement to the arrow on the scale. The device is comparatively compact and does not need attachments. It is easily used in mass worker surveys conducted in production conditions.

In the KIP plant, in academic and industrial laboratories, and among medical students we determined the extensor strength in 230 people.

In most persons, both in the experimental and control groups, the strength of the right wrist was stronger than that of the left. In 88 persons (76.5%) the extensors of the right wrist was (0.5 kg and more) stronger than the left. In 17% strengths were about equal and in 7 cases (6%) the extensors of the right wrist were weaker than those of the left.

These results correspond with those of others, especially B. B. Koyranskiy (1929). The author found a stronger right hand in 60% of workers who had not had contact with toxic substances. In the control group the right hand was stronger in 76.5 percent of cases, in personnel of "mercury professions" in 51% (59 persons). To this group belonged a higher percentage of persons with little difference in strength between the left and right wrists (23% as opposed to 17%). However, comparison of the indicated quantities by the standard error method does not confirm this difference. There were more than three times as many persons with weak extension in the experimental group as compared to the control group. In this case the percent of Teleky's symptom was statistically reliable. The data obtained confirms the validity of predicting the possibility of micromercurialism. The absence of a definite correlation between the frequency of distribution of Teleky's symptom and the appearance of micromercurialism indicates the possibility of its development independent of other symptoms, characteristic of mercury's effect on the organism.
The data of B. B. Koyranskiy shows that the higher the age the fewer the people contacting toxic substances who have weakened right hand extensors. Our studies showed that the 20 - 39 year age group was predominant (77.6%). This is thoroughly reflected in the obtained results.

Below is discussed material from clinical observations (from the data of occupational disease clinics of the Kiev Institute of Industrial Hygiene and the Kiev Medical Institute).

Data on 136 persons (81 men and 55 women) were studied. The age range were as follows: under thirty, 30 persons; 30 - 39 years, 62 persons; 40 - 50 years, 30 persons; over 50, 14 persons. Their occupational distribution: instrument makers and glassblowers, 30; electricians at transformer stations, 10; other occupations, 10; industrial and academic engineering and technical personnel, 26; medical workers, 8; personnel of scientific-research institutes and graduate school personnel, 34; employees of other enterprises, 6.

Work experience data: 34 persons, up to 4 years; for 68, 5 - 10 years; and in 34, more than 10 years.

These were ambulatory patients who complained of headaches, dizziness and all of the other subjective symptoms earlier described. In some bleeding gums, heart palpitations, impotence, were observed.

Neurological examination revealed a lowering of corneal reflexes, weakened convergence, an increase in tendon, periostal and skin reflexes with a broadening of the reflexogenic zone seldom producing irregular reflexes. Changes in the sensitivity sphere is characterized by depression of surface types of sensitivity of the distal sort and muscular tenderness. In almost all cases there were fine tremors of the fingers and eyelids and of the fingers in Romberg's position. Disruption of coordination (finger-nose, etc.) was not observed. In some cases there is horizontal nystagmus or sensitivity of the eyeball.

Neurological symptoms have much the appearance of the astheno-vegetative syndrome observed in a series of other effects of an exogenous and endogenic nature. Considering this relationship and the necessity for accurate differentiation of the asthenic-neurotic syndrome of mercury etiology from related "general somatic" disorders, we conducted a series of special investigations which established that: from the standpoint of cortical neurodynamics, changes in the functional state appear most often, as in more rapid nystagmus, under strong stress.

Most of the subjects had changes in the vegetative nervous system: increased sensitivity to temperature changes, especially to cold, periodic hot flashes in the head, neck, chest, hyper-salivation and increased sweating. Some of them had changes in skin color and more or less acrocyanosis, changes in the pilomotor reflex, and erupting red dermographism.

The general background of vegetative-vascular reactions as determined under pharmacological and thermal stress are characterized by insensitivity and variability. High unconditioned pressor reflexes predominated in caffeine and cold stresses according to A. A. Model' (1961) and appears specific for mercury effects.

In characterizing other clinical changes, we agree with A. A. Model' (1961) that "... discovery under hospital conditions of shifts in cortical neurodynamics, a disruption of the functional state of the vestibular analyzer and changes in vegetative-vascular reactions can be regarded as the result of re-arrangement of the functional activity of the whole organism with changes in the cortical and sub-cortical interactions, indicating an incompetence in neuroreflex adaptive mechanisms."

Descriptions of shifts and disruptions of mercury etiology appear as a result of analysis of therapeutic effects observed in the clinic during treatment of patients displaying micromercurialism. This effect, caused by normalization of
the given disturbance, appears more quickly and was developed to a greater degree than, when in the complex of therapeutic substances, unithiol is used.

For example: Subject V., age 34, a thermometer-maker with five years' experience where the mercury vapor concentration in the air of the work zone was 0.01 - 0.03 mg/m³. In the course of his occupation he developed systematic muscular traction of the left humerus and wrist when filling capillaries. He felt ill for six months without visible cause and complained of headaches, intensifying toward the end of work or when he was agitated. He felt dizzy and sleepy and out of adjustment. At the same time he felt astringency in the left hand and pain in the right hand.

His pulse was 68/mn., blood pressure 120/80 mm, the heart, lungs and internal organs appeared normal.

Neurological changes, including eyelid tremors in Romberg's position and positive Telekey's symptom, indicated mercury effects. His urinary mercury content before unithiol was 0.0187 mg/l and 0.075 mg/l afterward. Blood analysis: hemoglobin - 78 units (13%), erythrocytes 4,310,000, leukocytes - 4000, eosinophils - 4%, segmented - 59%, monocytes - 6%, ESR - 8 mm/hr. X-rays were normal, and the conclusion of the clinic was an asthenic-neurotic syndrome of "mercury" etiology and an occupational neuromyalgia of the right hand.

In this case the indicated nervous system changes appeared after one to two years' exposure of low concentrations of mercury. In the absence of complicating disorders, the increased urinary mercury output after unithiol indicated the "mercury" etiology of the asthenic-neurotic syndrome.

In another case:

Subject K., age 44, was a machinist - assembler of measuring devices, had worked thirty years and had been in contact with mercury for fourteen (hand-filling manometers, thermometers and other devices) The aerial mercury concentration in his work zone was 0.01 - 0.03 mg/m³. He complained of headaches, dizziness, increased irritability, emotional extremes, insomnia, apathy, trembling of the hands when attempting delicate motions and when under stress. Earlier he had been relaxed and amiable but in the last year, because of hand tremors and a tendency toward tears, strengthened by agitation, left his work. Additionally he complained of weakness, nausea, loss of appetite and frequent liquid stools. He had felt ill about six years. His pulse was 80/mm, blood pressure 100/55 mm, heart enlarged toward the left about 1 cm., cardiac rhythm was regular, his lungs appeared normal. He had a sensitive stomach. It was sensitive to palpations on the left side had a spastic colon and his tongue was moist and coated with a white film. He had some horizontal nystagmus, and 48 kg strength in both hands, insufficiency in Romberg's position and fine tremors of the fingers of the extended hand. Teleky's symptom was absent. The urinary mercury level was changed only after injection of unithiol (from traces to 0.047 mg Hg/l). Blood analysis: hemoglobin - 90 units (15 g%), erythrocytes, 5,350,000, leukocytes - 5,100, eosinophils - 3%, segmented cells - 61%, lymphocytes - 25%, monocytes - 8%, color indicator, 0.84; ESR - 3 mm/hr. X-rays of the digestive tract showed hyperplastic gastritis. He had spastic colitis localized in the sigmoid region. Conclusion of the clinic: Asthenic-vegetative syndrome of mercury etiology and spastic colitis. In this case a man suffering from chronic illness of the gastro-intestinal tract was in contact with mercury. He had the asthenic-vegetative syndrome with neurotic symptoms predominating. The correspondence of this syndrome with the presence in the urine of mercury after injection of unithiol is illustrative to the clinical symptoms of micromercurialism.

Other case histories are quite similar; lighter manifestations coupled with briefer terms of employment indicate initial stages of micromercurialism.

The neurological symptoms in the given cases were characterized by the presence of neurotic and asthenic phenomena and symptoms of vegetative dysfunction typical of micromercurialism: depressing, apathy, trembling hands, etc.
From the preceding descriptions it is evident that neurotic symptoms of heightened emotional lability predominate.

Vegetative disorders expressed as headaches, pain in the vicinity of the heart, increased sweating, metallic taste in the mouth, are often accompanied by pulse lability, vascular asymmetry, cardiovascular insufficiency reactions in ortho- and klinostatic reflexes, inadequate eye-heart reflexes and sharp irruptive dermographism.

In more advanced states asthenia and progressive neurotic phenomena appear. There is a drop off in fulfillment of ordinary work, complaints of sleepless nights and daytime drowsiness, often accompanied by spasms, inadequate response to injury and poor self image, especially with respect to minor changes in working conditions. These are associated with hand tremors under stress and when attempting fine work.

These clinical, physiological and experimental data indicate that early functional-dynamic disturbances involve changes in cortical neurodynamics, having a phasic character.

The first phase is characterized by destruction of strength and equilibrium of basic neural processes through weakening of the inhibitory and relative predominance of the excitatory process with the simultaneous weakening of the cortical influence on the subcortical region. This results in heightened excitability of the vegetative nervous system, especially its sympathetic region, which is extremely symptomatic of the first phase, being basically one of weakened inhibitory processes.

In the second phase, there is a gradual increase in exhaustability of cortical cells, vegetative-vascular reactions become inert, testifying to the predominance of inhibition processes. This appears to be the result of weakness in the higher branches of the brain which protects the more reactive parts of the central nervous system.

The syndrome known as mercury erethism involves peculiar disruption of the emotional sphere, and in the light of modern opinion, arises as a result of destruction of the complex interactions between the cortex and the optic thalami producing a neurosis caused by sharp weakening of cortical processes.

Micromercurialism is characterized by a prolonged retention of the phase of augmented cortical excitation with concomitant pathological lability of the vegetative nervous system. Transition into the second phase comes in the later stages of intoxication. Significant in the differential diagnosis of micromercurialism are: sleep and emotional disturbances, marred vegetative disorders, tremors and increased salivation.

These specific symptoms are relative. In connection with these accurate analysis of anamnestic and clinical data, working conditions and type of work is necessary for the correct diagnosis of micromercurialism. The mercury etiology of micromercurialism is confirmed by the presence in excrements (usually in the urine) of mercury, the content of which increases under the influence of unithiol.

Note another criterion, the explanation of which is necessary in establishing the etiology of the observed shifts and disturbances. We already stressed that along with the asthenic-vegetative syndrome of mercury etiology, symptoms may be caused not only by toxic action but by various infectious diseases, most of all influenza. In this, however, nervous system changes, as a rule, develop quickly, soon after the fall in temperature, and disappearance of catarrh, and then gradually level off. In micromercurialism vegetative dystonia and asthenia develop slowly, by degrees, gradually increasing in their intensity.

From clinical and statistical materials presented by us based on periodic investigations and special observations, clinical data, obtained under hospital conditions, suggests that in "non-specific" syndromes in persons having contact
with low concentrations of mercury, there are "specific" elements permitting interpretation of the syndrome as a phenomenon of micromercurialism.

CHAPTER VII

MODELING MERCURIALISM AND ITS MANIFESTATIONS UNDER THE EFFECTS OF VARIOUS CONCENTRATIONS OF MERCURY

"Try to claim that hygiene is not a social health science...Then you will see that experimental treatment of hygienic problems loses a great part of its attractiveness, because originality and independence can be significant only as they relate to the study of those factors, which in one way or another affect the health of humans as a social unit." (F.F. Erisman, 1883) (F. F. Erisman. "Foundations and Goals of Modern Hygiene Russkaya mysl, 1883, I, 38).

Experimental studies and investigations discussed in this and subsequent chapters refer to conditions of dynamic exposure of mammals to mercury vapors at room concentrations of 0.006 - 0.05 mg/m³ (mean concentration in individual series about 0.01 - 0.04 mg/m³).

A series of studies designed to correlate changes, caused by the effects of low mercury concentrations, with toxic effect, brought about by relatively high concentrations of mercury vapors (in separate tests -- vapors of ethylmercury compounds), were undertaken at mercury contents in the order of tenths, and in some series, thousandths of a mg/m³. The research was conducted in several species of laboratory animals -- white mice, white rats, guinea pigs, rabbits and cats. Inhalation exposure of the animals was done in an experimental chamber under conditions (stable for each series of tests) of controlled ventilation, temperature and relative humidity.

Daily six-hour exposures were made. The duration of the experiment was from 3 months - one year (in another series, up to one and one-half years).

Seeding occurred in chambers with a volume of 50 and 25 liters and also in a universal experimental chamber of original construction (capacity 925 liters) constructed in our laboratory.

Procedures for both types of chambers were identical. Air, flowing through each chamber, first passed over a metallic mercury (or ethyl compounds) surface, then having gone through the chamber is directed through three sequential absorbent compounds in a solution of iodine with potassium iodide to a rheometer and to an exhaust (air blower or water pump). The latter maintains continuous air circulation through the chamber. Changes in air temperature, flowing through the chamber, rate of flow, surface area of the evaporating metallic mercury (or mercury compounds), maintains the required concentration successfully. The continuity of the above factors secures the stability of the required concentrations.

During the experiment we observed the animals' behavior and weighed them.

To compare the picture of intoxication with data pertinent to mercury-caused effects and to evaluate the degree of its expression, simultaneous investigation of the morphology of the blood and dynamics of the mercury content of several biological substrates was done.

In most series, changes in the animals' behavior was not observed. In a few of them, by the end of the experiment there was some depression and adynamia, sharply depressed appetite; in others the animals hypersalivated.

More pronounced changes in behavior were noted in the last stages of the experiment in white mice, which were the most sensitive to the effects of mercury. In the first one to two months, their behavior, like that of the other species, did not differ from the pre-exposure pattern. By the two-three months from the beginning of the experiment, they acquired heightened reflex excitability, some increase in motor activity and then, adynamia and depression,
decreased appetite and lowering of response to external stimuli. At that time as in the majority of the other animals (white rats, guinea pigs, rabbits, cats) whose general behavior did not change, body weight did not drop, while in mice it fell significantly. In one of the series undertaken at an average concentration of 0.04 mg/m³, a tendency toward weight loss was evident among subject mice even in the first half of the experiment in the absence of external recording of toxic effect. Although in comparison with an analogous group of animals, exposed to ethylmercury compounds, this depression was much less significant. However, in comparison with the control group there was a noticeable tendency toward weight loss. (Figure 9)

In experiments with guinea pigs (at a relatively high concentration, 0.95 - 1.0 mg/m³) there was weight loss for the entire experimental period (Figure 10). A similar effect appeared also in the guinea pigs in experiments at average concentrations of ethylmercury compounds of 2 mg/m³ (in conversion to mercury).

Weight loss in comparison to controls was observed in the series of experiments with cats at relatively high concentrations (tenths of a mg/m³). Upon exposure to mercury vapors in concentrations in the order of hundredths of a mg/m³ the weight of the experimental animals was no different from the controls.

Only in some animals of other species were there the changes described for mice and these always in the later stages of the experiment. In some mice there was paresis of the extremities and clonic seizures (Figures 11 and 12).

Among animals of other species later in the experiments with higher concentrations, there were sharp changes, but those occurring in mice (paresis, seizures) were not observed. This excludes rabbits which were exposed to concentrations of 0.01 - 0.04 mg/m³ for a whole year. In some of them, after thirteen months with a background of increasing reflex excitability, we observed beginnings of tremors, ataxia and occasionally paresis of the hind feet.

The fact of increased sensitivity of white mice and rabbits (although to a lesser degree) to the effects of mercury was confirmed by morphological findings.

At concentrations close to 0.01 mg/m³ most animals display no symptoms of intoxication.

Blood changes during the experiments were most pronounced in white mice. In other species, hematological shifts were of a lesser degree although they did not differ in character from the changes observed in mice. These shifts were usually latent and appeared only in later stages.

The first series of experiments was undertaken under conditions of relatively intense mercury effect (0.45 mg/m³). Daily exposure - 6 hours. Total duration of exposure - 63 days (first series) and 118 days (second series).

In the first series of experiments lasting 15 - 25 days, no changes in animal behavior were noted. In the following 20 - 30 days activity of the experimental animals gradually lessened and adynamia, loss of desire to eat, increased reflex excitability and mild body tremor appeared. In that period weight loss averaged 18 - 23%, and at the end of the experiment, 30%. Five to eight days before the end of the experiment, 9 of the 30 mice developed paresis of the hind legs. Before death, some of the animals developed paralysis.

In the first 13 - 19 days of the experiment there was some increase in the quantity of hemoglobin and erythrocytes, then a gradual and insignificant decrease - erythrocytes from 9,1427,000 - 8,523,000: hemoglobin - from 99.2 - 90.4%. The number of reticulocytes increased from 13th day to the end of the experiment from 43.3 to 71.2 - 74.4%. In the first 12-13 days there was some leukopenia followed by leukocytosis. The total number of leukocytes decreased almost twofold in comparison with initial figures (from 12,140 to 6,772) and this was accompanied by a decrease in the number of all forms except mononuclears, the number of
which was unchanged. From the 13 – 14th day the number of leucocytes increased again, and from the 16th day of the experiment leucocytosis developed, rising to 16,588 by the 37th day of exposure. Toward the end of the experiment the leucocyte count was 9,400, that is, it was lower than initially. The increase in the total number of leucocytes occurred at the expense of growth of lymphocytes and neutrophils, and also as a consequence of some increase in the numbers of eosinophils and mononuclears.

Figure 9

CHANGE IN MOUSE WEIGHT IN THE FIRST HALF OF THE EXPERIMENT
(from a series of tests with an average mercury and ethylmercury phosphate concentration of 0.04 mg/m³):

At the end of the experiment the total number of leukocytes decreased sharply (8,522 - 5,259) with some decrease in the number of eosinophils and mononuclears. The number of neutrophils did not decrease. Young forms increased during further development of intoxication and reached a maximum (5.2 fold increase) just before death of the animals. Therefore the nuclear shift index increased towards the end of the experiment. The number of eosinophils beginning at the 14th day, exceeded initial levels 1.5 times and held at that point until the 37th day of the experiment. After the end of the experiment, they had dropped considerably - from 213 - 38, that is 5.6 times.

Turk cells appeared at the 19th day and persisted until death of the animals. They were at maximum from the 23 - 30 day of the experiment.

The prolonged action of metallic mercury vapor was accompanied by the appearance of polychromatophilic erythrocytes, and the rarer appearance of mononuclears with vacuolized cytoplasm.

There was an increased number of mitotic cells.

At the same time, degenerative changes in cellular elements of the bone marrow were observed only in those animals in which previous signs of intoxication were most evident.
Especially interesting is data obtained in the second test series. During the first 40 - 60 days of the experiment there were no evident marked changes in animal behavior. The mice were active, desired food and maintained their weight. Subsequently some of them diminished their activity at exposure times and for 2 - 3 hours afterward.

In comparison with controls, these animals did not eat well and were less active. At the end of the experiment most of the mice had lost 12 - 16% of their body weight.

At this concentration there were insignificant changes in red and white cells of the blood.

Hematological shifts in the second half of the experiment were characterized by some increase in the amount of hemoglobin, erythrocytes, reticulocytes and the total number of leucocytes. Thus, in comparison with initial data, by the 65th
day hemoglobin had increased 0.9%, the number of erythrocytes by 500,000, reticulocytes by 4.4% and the leucocytes by 1,520.

The number of neutrophils increased twofold (from 145 - 294) with the simultaneous appearance of young forms of neutrophils.

Beginning with the 45 - 50 day from beginning of exposure, polychromatophilic erythrocytes appeared in the peripheral blood, also erythrocytes with Jolly bodies.

Turk cells were encountered, but not after thirty days.

In the myelograms of three mice, killed on the 10th, 20th and 35th day of the experiment, there were no marked changes observed in the hematopoietic function of the bone marrow. In mice killed at the 37th day, parallel to changes in the peripheral blood such as polychromasia (++) and the appearance of individual normoblasts in the bone marrow certain changes toward elements of erythroid growth were observed. Thus, maturation of erythrocytes was about 0.75, and the correspondence of leucoblastic elements and erythroplastic was about 1.97, indicating certain shifts to an increased number of young cellular forms of the erythroid series, and also growth of the total number of erythroid elements in the bone marrow. The maturation indicator of neutrophils in the bone marrow of these mice was at the high level of average quantities established by us in control animals and equalled 2.03.

In mice with visible evidence of mercury damage, hematological changes in the bone marrow and peripheral blood were more developed. By the 43rd - 65th days of the experiment there was some increased regeneration of elements in the
erythroid and myeloid series: insignificant increase in the number of myelocytes, metamyelocytes and erythroblasts in the bone marrow, simultaneous small neutrophil shifts to the left and increased numbers of reticulocytes in the periphery (Table 21).

Changes in the peripheral blood of white mice subjected for two months to the effects of high mercury concentrations developed parallel hemopoeitic shifts in the bone marrow. These changes in the first half of the experiment had a regenerative character. After further intoxication development this was linked to degenerative phenomena.

During an experiment in separate groups of animals we conducted mercury determinations of the blood, urine and feces. The results of some of these determinations have already been covered by us in a series of published works (1951, 1962, 1963).

These studies showed that mercury is excreted from the body irregularly. Between the degree of excretion of mercury from the body and the evidence of a mercury effect there is no definitive relationship. As a rule, elimination of mercury from animals subjected to the action of low mercury concentrations, begins quickly (within one to two weeks) from the beginning of the experiment and continued for quite some time (two to four months and longer) after cessation of mercury contact. This elimination on a background of the chronic effect of mercury and its compounds in concentrations on the order of hundredths of a mg/m3 is characterized by rising and falling periods, in the dynamics of which regularity could not be observed. (Figure 13).

The absence of a correlation between the urinary mercury content and evidence of mercury damage was also noted in tests at higher mercury concentrations (Figure 14).
Experimental observations on the dynamics of mercury elimination from the body of animals confirm conclusions on the irregular excretion of mercury with the urine and of the absence of a definite relationship between the degree of elimination and evidence of a toxic effect observed by us in our studies of mercury workers.

Analogous conclusions come from results of determining mercury in feces of experimental animals: its content for the duration of the experiment increased sharply and then fell markedly. In this, as in preceding observations, on the dynamics of urinary mercury excretion, much dependence between these fluctuations in the course of intoxication could not be proved.

Data characterizing mercury content dynamics in the blood of animals is presented in Figure 15.

Even in the first days of the mercury effect, as a rule, mercury is observed in higher concentrations, than at the end of exposure. We couldn't show a relationship between the course of intoxication and the blood mercury content. Indeed, there is a tendency towards an inverse relationship, in which in the first days of exposure, when clinical intoxication was not evident, the mercury content in the blood was significantly higher than in the later period when signs of poisoning were evident. It is possible that upon the entry of mercury into the body, it is adsorbed to a great degree by the organs and forms depots in them. Results of determining mercury content in mammalian organs and tissues will be treated in data analysis of morphological change characteristics of organs and tissues.

**Figure 13**

**MERCURY EXCRETION DYNAMICS FROM URINE OF EXPERIMENTAL ANIMALS SUBJECTED TO LOW MERCURY VAPOR CONCENTRATIONS AND ETHYLMERCUry COMPOUNDS**

(a series of comparative experiments on mice: average mercury concentration in the air - 0.04 mg/m³, urine was collected after daily six hour exposure in the course of eighteen hours)

- Animals subjected to
  - Low mercury vapor concentration
  - Ethylmercury compounds

Average daily quantity of mercury excreted (based on the results of one mouse) by the experimental group.

0.043

0.03
Figure 14

DYNAMICS OF URINARY MERCURY EXCRETION IN GUINEA PIGS AFFECTED BY RELATIVELY HIGH MERCURY CONCENTRATIONS

![Graph showing urinary mercury concentration with an aerial metallic mercury content of 1.2 mg/m³ and 2.0 mg/m³ over 65 days from the start of poisoning.]

Figure 15

MERCURY CONCENTRATION IN THE BLOOD OF EXPERIMENTAL GUINEA PIGS AT AERIAL MERCURY CONCENTRATIONS OF 1.2 mg/m³ AND 2.0 mg/m³

![Graph showing blood mercury concentration over 60 days from the start of poisoning.]

Aerial mercury concentration:
- 1.2 mg/m³
- 2.0 mg/m³
CHAPTER VIII

PROTEINEMIC SHIFTS IN EXPERIMENTAL MERCUROUSM

The reaction between mercury and functional groups of tissue protein plays a leading role in its action mechanism. The inactivation of these groups, primarily the sulfhydryl, and the effect on the chemical structure of the cellular proteins themselves enables mercury to change the biological properties of tissue proteins. Contemporary biochemistry has accumulated significant material on the role of -SH groups in several processes, especially, of their activating effect in a series of enzyme systems. This fact assumes a significant role in the carrying out of many of the most important physiological functions. To understand the effect of -SH groups on these systems it is necessary to understand their direct participation in a series of physiological processes. This position agrees with that of Kh.S. Koshtoyants (1951) on the role of -SH groups in neural activation and the experimental observations of B.I. Gol'dshteyn (1955) on the significance of -SH groups in the act of muscle contraction, etc.

A number of recent experimental observations elucidating the role and significance of -SH groups during development in the organism of a series of biochemical and physiological processes have shown how various toxic substances affect the structural features of tissue proteins and their reactive groups. These studies involve broad cooperation among Soviet chemists, pharmacologists and toxicologists in the realm of synthesis and experimental analysis of various thiol compounds used as antidotes for many pathological conditions. Analysis problems of action mechanisms of toxic substances on the functional groups of tissue proteins were the basis of a special conference on thiol compounds in medicine held in Kiev (A.I. Cherkes, N.I. Luganskiy, et al., L957; S.I. Ashbel', 1959; B.S. BraverChernobul'skaya and C.A. Belonozhko, L959; A.Yu. Izergin, 1938). The action of mercury on tissues was presented in the works of Sh.A. Galoyan (1959), N.M. Kostigova (1957), T.M. Turpayeva (1950), V.A. Shalimova (1956). These studies were undertaken under all sorts of mercury entry conditions except via the respiratory route which has such a principal place under working conditions, and dealt with other vapors which contain a high proportion of mercury salts.

Experiments showed the effects of low concentrations of mercury on the process of resynthesis (renewal) of tissue proteins, protein formation activity in the liver, the structure of protein molecules and the level of sulfhydryl groups in various organs and tissues.

The first series of experiments investigated the uptake intensity of radioactive amino acids, especially methionine, labeled with S35, in plasma proteins and liver under low mercury concentration conditions in animals (0.01 - 0.03 mg/m3, average concentration 0.014 mg/m3) during 5 1/2 months of daily six-hour exposure.

The use of labelled amino acids and other compounds permits determination of the speed of resynthesis of tissue proteins. The speed of isotope uptake indicates the intensity of amino acid inclusion in tissue proteins. Data obtained by S.V. Anlchkov (1955) indicates that inhibition of amino acid uptake "is one of the first morphological signs of damage."

Our studies with plasma proteins as the most dynamic and labile system has great relevance to the physiological condition of the body. We concluded that the transformation of plasma proteins in liver protein and its reverse is one of the pathways of tissue protein formation.

Radioactive methionine injected subcutaneously was the indicator substance. Radioactivity was determined with a type MST17 counter on a type B apparatus. In all experiments the labelled methionine was given in doses which did not exceed the standard. Blood and liver examinations taken from both experimental and control groups showed that within 18 hr. after the injection of methionine the radioactivity of rat plasma proteins, subjected for 143 days the effects of the indicated mercury concentrations, was about 4.2% in the experimental and 9.3% in
the control group. Thus radioactive methionine uptake was lower in experimental rats by a factor of 2.

Another test series involved longer exposure (166 days) and measured the labelled methionine uptake 3, 6, 18, and 30 hours after injection. As shown by Figure 16, these conclusions are borne out by the respective curves. Uptake reached maximum by the third hour after the dose and then gradually decreased, reflecting the exit of amino acids from the plasma proteins.

In rats subjected to the effects of low mercury concentrations, the methionine uptake into plasma proteins proceeds not only less intensely but later than in control animals (Figure 16).

Our data reflect changes arising under the influence of very low intensities of mercury acting on protein biosynthesis in the liver and blood. Note that these changes in tissue protein biosynthesis has been observed by many researchers and also under the effect of toxic substances having a pronounced hepatotropic effect (P.G. Garkavi, I.P. Ulanova and P.G. Garkavi, 1961; N.I. Ivanov, V.K. Modestov, Yu.M. Shtukkenberg, et al., 1955, A. Marschak, 1941).

These changes are significantly connected with disorders of liver function. An experiment with guinea pigs subjected to mercury vapor in concentrations of 0.01 - 0.03 mg/m3 for a total exposure of 104 days at the end of which a thymol test was done, reflected changes in the structure of blood proteins. We suggest that the turbidity of the serum is connected with an increased gamma-globulin content and indicates significant disruption of plasma protein synthesis. The degree of this depends to a great extent on the amount of liver damage.

All the thymol tests showed that all animals were sharply positive (10 - 16 turbidity units). At the same time tests from control animals were negative. This data confirms the opinion of several authors of the diagnostic value of this test in circumstances where other functional tests are useless.

The second functional indicator is the ability of liver tissue to reduce dihydroascorbic acid (DAA) to ascorbic acid (AA). The intensity of this process guarantees the preservation of the body's C-vitamin reserves so necessary to normal function.

To determine this reduction, we used the method of M. Schultze,
E. Stetz and G. King (1938) as modified by S. I. Vinokurov and M. L. Butom (1930). The ascorbic acid content of liver tissue was determined according to Til'man's Method in the deproteinized filtrate by titration with the redox indicator 2,6-dichlorophenoldiphenol.

Figure 17

**AVERAGE QUANTITIES WITH CONFIDENCE LIMITS OF ASCORBIC ACID CONTENT (AA) IN THE LIVER AND THE PERCENT REDUCTION OF DEHYDROASCORBIC ACID (DAA) TO AA IN EXPERIMENTAL AND CONTROL GUINEA PIGS**

The data showed that this reduction occurs less intensely in experimental as compared to control animals (0.66 - 11.3% and 14.3 - 25% respectively). (Figure 17)

This experiment confirms earlier opinion of the effect of low mercury concentrations on the development of functional insufficiency of the liver. This is followed by definite morphological changes, especially the appearance of parenchymatous dystrophy, mostly reversible.

Additionally we determined the intensity of renewal of tissue proteins, especially plasmas in the liver, with radioactive amino acids.

It is known that isolated sera has a definite capability to bind radiomethionine (M. G. Kritsman, A. S. Konikova, 1959; R. Brunisch and M. Luck, 1959; R. Schwet and H. Borsook, 1953). It is also known that certain chemical substances, such as highly active thiol nuclei, react with tissue proteins and destroy the chemical structure of their molecules, depressing the reaction properties of tissue proteins. Unsolved is the problem of how toxic effects arise at low intensities. Mercury can change the chemical structure of a molecule without producing an evident toxic effect.

In our in vitro determinations of the bonding intensity of radioactive methionine by plasma proteins, control and experimental rats, poisoned by metallic mercury vapor were killed by piercing the jugular vein, blood was collected in glass vessels the sides of which had been rinsed with 19% sodium citrate. The plasma was then centrifuged into its formative elements and divided up into 2 ml samples. To 2 ml plasma was added 2 ml phosphate buffer at pH 7.5 and 1 ml of labelled thionine solution (150,000 imp/mm) which registered 750,000 imp/min on a counter. These vials were incubated 2 hr at
37°C. After the protein was precipitated by 10% trichloroacetic acid solution (TCA). The precipitate was washed 6-7 times in 5% TCA and then recentrifuged. The final wash water radioactivity was measured by a Geiger-mueller counter. The precipitate was suspended in 10 vol. alcohol for extraction of lipids. After alcohol treatment the protein was centrifuged and the alcohol wash was repeated twice and with ether twice. After drying at 80°C the radioactivity was determined (Figure 18).

The reactive capability of the plasma proteins of experimental animals is gradually lost over a prolonged period (82,143,186 days.) Less prolonged exposure (33-52 days) did not produce this relationship. The change in protein radioactivity was statistically insignificant. The significant decrease in intensity of binding of radiomethionine by proteins of isolated plasma from the experimental animals is noted during the third month of the experiment and continued almost without change during the entire succeeding period, while the control quantities at the end of the experiment were higher than their initial levels (Figure 19).

Mercury blocks free sulfhydryl groups of proteins. According to the data of B.I. Gol'dshteyn (1955), it oxidizes, usually, the thiogroups of cysteine, one of the basic sulfhydryl group donors. In the process of blocking by mercury ions of thiol groups, cellular proteins lose their reactive properties through the action of mercury and tissue proteins, the destruction of the chemical structure of their molecules, goes by a type of mercaptidoformation, in the course of which mercury reacts with both SH groups, distributed along parallel polypeptide chains of the protein molecule:

\[
2R-SH + Hg++ \rightarrow Hg+2H+ \rightarrow R-S-S-R
\]

Methionine easily loses its OH group as a result of transmethylation through while disulfide bonds (S-S) can link to the protein molecule. But occasionally mercury blocks this bonding or a part of it.

There is interest in the work of G.I. Kulik (1958) of our laboratory. Difference in the course of the experiment suggested that he used higher mercury concentrations (on the order of tenths of a mg/m3). The first series of these investigations was done on a group of rats which, throughout the whole experiment, received unithiol in 50 mg/kg doses. The second series was conducted without the administration of this thiol preparation to the poisoned animals. Finally the third series of rats was given 600 mg/kg unithiol, but only at the end of the experiment. Parallel observations were done on a group of controls.

Results showed that increased concentration of metallic mercury vapor changes the reactive properties of plasma proteins not towards the decrease shown in previous experiments but towards an increased intensity of binding labelled methionine. Only in the initial period of mercury effect was there some decrease. Under increased exposure, the radioactivity of plasma proteins in the experimental animals increased significantly, exceeding the radioactivity of the plasma proteins in the controls by 18-20%. The introduction of free SH Groups as dithiol-unithiol (sodium 2,3-dimercaptopropane sulfonate) in the early stages of effect, as a rule, restored the reactive capacity of the protein to control levels. Also dithiol, given at the end of exposure, despite significant doses, did not have the desired effect. Truly, the increased intensity of radioactive methionine uptake by plasma proteins in the given case is explained by denaturation or changes close to it of proteins, analogous to the action of agents such as colloidal silica (T. I. Kazantseva, 1958) and a series of other toxic substances in comparatively high concentrations (I. V. Savitskiy, et al., 1959).
Experimental data of A. G. Pasynskiy, et al (1955) and also E.E. Shnol (1953) showed that bonding of labeled amino acids by proteins can serve like denaturation as an indicator, but can register finer changes arising as the result of actions significantly less intense than those indicated by denaturation.

Under the influence of low mercury concentrations such as in the initial stages of more pronounced mercury damage, the decreased intensity of radiomethionine bonding by plasma proteins is caused by mercury blockage of the reactive groups, especially the SH- groups of protein. This confirms the fact of weakening or even absence of a marked effect in cases of unithiol injection. The latter combines with the group of thiol compounds containing free SH- groups having the capability of binding metals or reacting with SH groups of enzyme proteins blocked by them. The high antidotal effectiveness of unithiol in mercury cases is due to its causing the formation of a stable cyclic complex with metal upon entry into the body. This metal-thiol complex is more resistant (less dissociable) than the metal-biological substrate existing before administration of unithiol. Thus, unithiol forms with mercury a cyclic complex, removing blockage of functional groups of tissue proteins. The release of protein sulfhydryl groups, blocked by mercury, normalizes the binding of radioactive amino acids by isolated plasma proteins, restoring the reactive capacity of the protein molecules.

Therefore reduction in radiomethionine uptake can indicate the effects of low mercury concentrations producing blockage of free SH- groups.

Special studies were undertaken to determine the content of SH- groups in soluble liver proteins.
The determination was made by the special ferricyanide method of A. Mirskiy (1941) as modified by A. S. Tsiperovich and A. L. Loseva (1948). During the experiment, Ye. M. Kedrova (Institute of Biological and Medical Chemistry Academy of Medical Sciences SSSR) recommended changes at several points in the investigation, such as modifications in the Kjeldahl protein determination method.

A. Mirskiy's method determines only free SH- groups in the protein molecules. We also determined SH- groups in native protein by investigating its content in denatured protein in order to detect the total SH- content, both free and bound (according to the classification of E. Barron, 1951). We added to one of the two portions of protein solution, besides phosphate buffer (pH 6.7 - 6.5) and KCN, 1 ml urea. Further analysis was accomplished by a method described by A. S. Tsiperovich and A. L. Loseva with the addition, at the final stage, of 0.05 ml KCN solution and 0.5 ml ferrous sulfite, specially prepared, to the 10 ml of centrifugate. Colorimetry was done after 15 minutes in a FERMI-1 apparatus with a red filter.

The SH- group content in the soluble liver proteins were calculated in percents of cysteine in relation to protein and in micromols (uM) per gram of nitrogen.

The SH- group content of soluble liver proteins after addition of the denaturant (urea) increased sharply (Figure 20). This effect is caused by release of so-called masked SH- groups, which in native protein do not react with the given reagents for SH- groups and become functional only after protein denaturation.

The denaturation process exerts a definite effect on the reaction capability of SH- groups of proteins. The basis of this process lies in intermittent changes in the basic configuration of the protein molecule, which, according to A. G. Pasynskiy (1952), arise as a consequence of weakening or disruption of hydrogen, nonpolar and salt-line bonds inside the protein molecule. He suggested that SH- groups found in protein in the bound state are frequently cyclic and easily opened upon denaturation of thiazolinide structures.

For denaturation of the usually freely distributed peptide chains, one must consider not only their relation to each other but with various chemical reagents. A consequence of this reasoning, according to A. Mirskiy (1941) is that thio groups are easier to detect (with certain agents).

A comparison of SR- group contents in two groups of animals is shown in Figure 21.

The difference observed in "total" SH- group content of liver protein in experimental and control animals, cannot be explained by "masked" SR- groups. This position was confirmed during subsequent analysis.

The content of free (reactive) SH- groups of soluble liver proteins in experimental rats toward the end of the experiment (by the 151 - 181 day) was lower than in the control animals. Correlation of average quantities and their confidence limits showed that decrease in the number of free SH- groups is statistically significant. Simultaneously, the content of 'masked' (bound) SH- groups did not change, a very easily confirmed observation (Figure 22).

The first series of experiments showed that low mercury concentrations depressed the SH- group content of tissue proteins, causing blockage at the expense of free thiol groups.

Further verification is shown in the results of three series of experiments (Table 22). In this series SH- determination was done by the amperometric titration method of I. Kolthoff and W. Harris (1946) as modified by S. I. Nistratova (1959).

The table shows that in experimental animals there was a slight depression in SH- group content of blood serum by the end of the 1 - 2 months which was statistically insignificant. There was a significant difference in the correlated average quantities in the blood serum by the 3- 4. months of
exposure. At that time, the figure for the controls was 26.2 (+/- 5.5) μM/100 ml.

This diminution in SH- groups was also observed by the 5 - 7th month after initiation of exposure, although in this case, the difference in correlated average quantities was not as significant as in the previous case. The degree of depression of SH- groups in blood serum is not directly dependent on length of mercury exposure but is determined by the basic dynamics of mercury circulation in the blood. Under the chronic action of mercury vapor, the latter was detectable in the blood in various concentrations throughout the experiment. The dynamics of blood mercury content reflects the increases and still more quickly drops. After prolonged exposure to mercury its blood content, as a rule, is lower than at the beginning.
Despite this depression, mercury is still detectable after 3 - 14 months. In connection with the results described above, we analyzed the intensity of protein bonding of radioactive methionine in vivo and in vitro experiments which confirmed the limiting synthetic function of the liver and of the blockage of SH- groups in the blood serum.

The degree of depression of SH- group dynamics depends on the length of the mercury effect (Table 23). Thus, after 3 - 4 months there was a statistical difference in the average quantities. At the end of the experiment, (5 - 7 months) this difference was statistically significant and indicates that SH-group content of the liver in u/100g tissue in the experimental rats was 0.48 +/- 0.064., significantly lower than in the control rats (0.72 + 0.16). Data obtained with amperimetric titration agrees with data obtained with ferricyanide method.

Decreased resynthesis because of SH- groups blockage was also detected in rat lung tissue although the depression was not as pronounced as in the liver.

To a lesser degree such a correspondence exists in the cardiac muscle and was observed 5 - 7 months after the start of the experiment. The SH- group decrease was statistically significant.

SH- depression in the brain, even after 5 - 7 months, did not differ appreciably between the control and experimental rats.

We can conclude that prolonged exposure to low mercury concentrations does not affect total brain tissue. Both in our investigations as well as in experiments of other authors it is shown that mercury in relatively small quantities in comparison with such organs as kidneys, liver and lungs is constantly revealed in the brain of animals in all cases of prolonged exposure to it. Evidently it deposits in brain tissue and reacts with the functional groups of proteins, but does not appear to reduce the number of SH- groups. Secondly, the decreased concentration of SH- groups in brain tissue upon the administration of mercury in comparatively higher doses is not as pronounced as in other organs.
Data of Sh. A. Galoyan (1959) indicates that under the effect of mercury, there is produced in experimental rats a disappearance of conditioned reflex extinction. In the brain tissue there was blockage of 0.1 – 0.2% of all free SH-groups, when mercury is present in extremely small (0.0015 mg/g tissue) quantities. This data agrees with that of V. A. Shalimov (1956, 1960) possibly indicating that the brain retains mercury differently because the localization

---

**TABLE 22**

- SH Group Content in Blood Serum of Experimental and Control Rats at Different Times After the Beginning of the Experiment (in µm/100 ml)

<table>
<thead>
<tr>
<th>Time from the start of experiment</th>
<th>1 – 2 months</th>
<th>3 – 4 months</th>
<th>5 – 7 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental</td>
<td>Control</td>
<td>Experimental</td>
</tr>
<tr>
<td>32</td>
<td>29</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>29</td>
<td>29</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>34</td>
<td>29</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>22</td>
<td>32</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>43</td>
<td>30</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>33</td>
<td>34</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>35</td>
<td>29</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>32</td>
<td>20</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>29</td>
<td>26</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>13</td>
<td>22</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>23</td>
<td>28</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>33</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27±4.2</td>
<td>28.4±2.2</td>
<td>15±5.5</td>
<td>26.2±4.7</td>
</tr>
</tbody>
</table>

**TABLE 23**

- SH-Group Content (in µm/100 mg Tissue) in Liver Tissue of Experimental and Control Rats

<table>
<thead>
<tr>
<th>Time from start of experiment</th>
<th>3 – 4 months</th>
<th>5 – 7 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>0.65</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>0.42</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>0.66</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>0.51</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>0.63</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>0.54</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>0.62</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>0.65</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>0.34</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>0.37</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>0.61</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>0.62</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>0.54</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>0.55±0.06</td>
<td>0.66±0.056</td>
<td></td>
</tr>
</tbody>
</table>
of SH-groups in the microstructure of the brain is by no means homogeneous. Materials of V. V. Portugalov and V.A. Yakovlev (1959) indicate that in the microstructure of various separate parts of the central nervous system (CNS) the number of thiol groups is not uniform. Thus, to observe the quantitative changes in sulphydryl groups of brain tissue, arising under the influence of mercury, one must produce not only "summary" determinations of SH- groups in the total brain, but determine them in the separate microstructures. Here another analogy is appropriate. The mere accumulation of mercury in the brain tissue provides an inadequate neurological picture to indicate a toxic effect.

M. Berlin's autoradiography method (1963, 1966) allows the selective determination of mercury in separate brain structures, greatly clarifying the problem. The accumulation of mercury in brain tissue is not as significant as in several other organs, but it is observed in parts of the brain in quantities equal to the massive depots in the body, particularly the liver. The selective "topography" of mercury distribution in CNS structures will determine the corresponding localization of primary reaction sites of mercury with free thiol groups.

The effects of low mercury concentrations not only show up the intensity of the course of protein metabolism, but to a definite degree can alter the structure of the protein molecule. They form stable complex compounds of mercury ions and tissue proteins and block the functional groups of cell proteins.

Low mercury concentrations affect a series of specific protein functions -- enzymatic, immunological and hormonal. According to V.A. Belitser, 1950, 1954.; A. G. Pasynskiy, 1952, the activity of specific proteins is directly dependent on the presence on the surface of their molecules of special reactive centers, composed of molecules of special reactive centers, composed of an aggregate of amino acids or separate groups. Changes in the chemical structure of the protein molecule, caused by the disorganization of these centers of mercury can decrease the specific activity of enzyme systems, immunity factors, hormones, etc.

Shifts in specific protein activity in combination with depression of synthetic processes and the prevalence of destructive changes, illustrates the general resistance of the organism to various harmful agents. This is the basis for inquiries into the appearance of latent effects arising under the influence of small mercury concentrations using methods of immune reaction analyses and analysis of certain endocrine functions.

CHAPTER IX
THE EFFECT OF MERCURY ON CONDITIONED REFLEX ACTIVITY

In analyzing the toxic activity characteristics of a series of occupational poisons, especially mercury and its compounds, the majority of investigators assumed that poisoning of the vegetative nervous function, of the subcortical ganglia, was primary. Later observations under experimental and clinical conditions showed that the pathogenesis of chronic mercury poisoning has a leading role in CNS changes especially of the highest regions, the cerebral cortex (E.A. Drogichina, 1959, 1962; A.O. Ivanov-Smolenskiy, 1939, 1949; L.G. Okhyanskays, 1954.; M.N. Sadchi-Kova, 1955; M.M. Gimadeyev, 1958; V.N. Kurnosov, 1962, et al.)

This chapter will discuss higher nervous activity under the prolonged experimental conditions (4 - 5 months) involving daily six-hour exposures to an aerial mercury concentration of 0.085 - 0.2 mg/m³ (first series), 0.01 - 0.02 mg/m³ (second series), and 0.006 -0.01 mg/m³ (third series). The experiment used cats with conditioned reflexes indicating the latent reflex period (time from stimulus initiation to threshold) and threshold time (duration of the animal's movement toward food).

In most laboratories evaluation of conditioned reflex activity changes produced by toxic substances is based primarily on data from rabbits and rats, more rarely, white mice. Cats are seldom used, as a rule. Observational results from
cat experiments obtained not only from the toxicology laboratory of the Kiev Institute of Industrial Hygiene and Occupational Diseases (Ye. I. Spynu, 1954; Yu. S. Kagan, 1961; L. I. Medved', 1961; et al) but from our laboratory (V. S. Buryy, 1959; I. V. Savistkiy, 1959) indicate the undoubted advantage of cat experiments. First of all, cats differ from the above animals in their highly organized higher nervous activity and also as experimental animals with which it is significantly more possible to set up parallel investigations for determining other indicators of toxic effect.

A feature of our method is the use of an original device for detecting "intersignal" times between two feedings, in cats trained to a system of positive and negative conditioned reflexes, alternating in strict sequential time intervals (1 1/2 minutes).

Developent of specific conditioned motor reactions begins with formation of a positive conditioned reflex.

All experiments were made under the same conditions previously described, that is a series of alternating conditioned excitations given on various days of the experiment was constant. This group of experiments was done in cats (four in each series).

Before the beginning of exposures the type of higher nervous activity characterizing the animals' response to various kinds of chemical substances was determined.

Note that individual responses to given stimulus appeared during conditioned reflex developent. At the time one cat oriented quickly to novelties in the experimental chamber, easily forming condition reflexes, others under the same conditions were slow to orient and comparatively inert in reflex formation. For a fuller characterization of the types of higher nervous activity of the test animals we studied the character of conditioned reflex extinction and restoration, using as a test the increase (in time) of differentiation and investigated conditioned reflexes to increased animal feeding stimulus (after a day of hunger).

Observations in the first series were made on cats that were highly unbalanced with predominance of the irritable process.

Results showed that daily six-hour exposure to 0.085 - 0.2 mg/m3 mercury vapor produced noticable shifts in conditioned reflex activity of test cats 1, 2, 7. These shifts involved reduced conditioned reflex response to weak stimuli (white light) and in stronger stimulus (buzzer). However conditioned reflexes to stronger excitation in the first 4 - 5 weeks of the experiment left higher reflexes to weaker stimulus, reflecting the strong integrity, in this period, of strong inter-relationships between reflexes. Behavior in these cats after 2 - 3 weeks reflected a tendency toward strengthening active inhibition processes which is confirmed by results of special tests shown in Figure 23.

A consequence of short-term strengthening of differentiated inhibition and decrease of conditioned reflexes in test cats is the marked tendency toward faster extinction of conditioned reflexes. If at the beginning extinction in cats 1, 2, 7 occurred after 2G -conditioned signals, less time was required during exposure (7 - 13). Toward the end of the experiment (7 - 8th week) lowering of conditioned reflexes was more developed. Weak stimuli (light) called forth slower responses. In some cats (especially 2 and 7) reflexes conditioned to the corresponding signals began to fall off. There was no correspondence between degree of conditioned reflex activity and character (intensity) of the activation stimulus. On a background of growing animal reaction, shifts to stronger stimuli (buzzer) began to appear to a lesser degree in comparison to the effects of weaker stimuli (light) (Figures 24 and 25).
During this period cats were somewhat adynamic and sharply inhibited. Feeding and orientation reflexes were noticeably depressed.

There is special importance in the normalization dynamics of these shifts after cessation of exposure. Within 9 - 17 days after the end of the experiment the cats had recovered much of their responses to the conditioning stimuli although the conditioned reflexes responses lessened. By the 28 - 33rd day from the end of exposure, conditioned reflexes to positive stimuli normalized, however the test of lengthening of differentiation showed that the action of negative stimuli set-in earlier than that noted before exposure. For full conditioned reflex extinction 5 - 8 signals were required, while at the beginning 20 - 140 were needed. These signs of differential inhibition weakening and "easing" of
extinction lasted 7 - 12 days and then normalized, returning to the initial level. Since in these experiments all cats had the same type of nervous system, in this case we could not distinguish any difference in the phenomenon of mercury action in direct relation to typological peculiarities of the individual animals. However, it was possible to tag the shifts in each cat as being of one or another type. Thus, for example, the changes in cat 7 were more pronounced than in the others (Figure 26).

Another dynamic appeared in the analysis of data from observation of cat II. This cat was also a strong type but with a predominately excitatory process. Under the influence of mercury the excitatory response weakened earlier than the inhibitory (Figure 27). Conditioned reflex changes in the early period are shown in Figure 28. It conveys the impression that mercury-induced shifts were more developed in this cat than in cats also of a strong type but in which the inhibitory process predominates.

Relatively high mercury concentrations produce earlier signs of toxic effect in test cats with this strong type of nervous system in the form of short term internal inhibition processes (differentiation, extinction) and more resistant progressive weakening of the excitatory process. Subsequently, active inhibition weakens as shown by lengthening of differentiation followed by response reactions to negative stimuli.

Positive conditioned reflexes, according to data of this series decrease initially according to a type of narcotic phase during nondestructive strong interactions among reflexes, and then with the destruction of these in a kind of paradoxical phase.
The latter is replaced by a diffuse cortical inhibition also spreading to the sub-cortical region (inhibition of unconditioned feeding and orientation reflexes). Restoration of cortical function occurs in its release from inhibition of the conditioned reflex influence. Later the active inhibition process normalizes.

In this series of experiments note two circumstances: first - the appearance of the above indicated shifts in the absence of any kind of external appearance of intoxication, second - the presence of a definite relationship between the type of shift that develops and the departure from individual reactivity (typological features) of the organism.

The second series of experiments indicate that higher nervous activity changes in the test cats were less highly developed in comparison with animals of the first series, primarily because of lower mercury concentrations of this series. Cats 3 and 5 show typological features of the strong type in their nervous system with a predominance of the excitatory process. In the first of these until the eighth and in the second until the seventh week from the beginning of the experiment, conditioned reflex activity changes did not appear. Only at the beginning of the 7th and 8th week respectively was there a shortening of the latent period and threshold time in response to a conditioned stimulus. Recovery proceeded gradually during the 7 - 8 weeks following the end of exposure (Figures 29, 30).

In cat 6, there was no noticeable change in conditioned reflex activity by the 18th week. Functional normalization in this cat occurred earlier than in the others, by the end of the sixth week (Figure 31).

The most expressed and earliest appearing conditioned reflex activity changes were in cat 8, referred to us for its weak activity with a predominant inhibition process. These changes appeared in the sixth week from the start of the experiment, while strengthening of the excitatory process in this cat was not detected. Until changes in positive conditioned reflexes appeared, there was no disruption of differentiation. Beginning at the seventh week, leveling off began, and then paradoxical and further ultra-paradoxal phase, prolapse of
reflexes to white light, sharp weakening, together with stimulation, and inhibition of processes arising from strong passive inhibition of cortical cells (Figure 32). Recovery of conditioned reflexes and differentiation occurred in this cat during 14 weeks after cessation of exposure. Weakening of internal active inhibition upon prolongation of mercury action was demonstrated during various periods of the experiment by the use of these with prolonged action of differentiated stimuli (up to 180 seconds). This "release" occurs significantly less often than before exposure.

The third series of experiments measured conditioned reflex activity in cats exposed to less than 0.01 mg Hg/m3 and the possible reversal, of damage to higher nervous activity caused by SH- group blockage by administration of substances containing active -SR groups. Mercury vapor concentrations from 0.006 - 0.01 mg/m3 produced effects on and damage to conditioned reflex activity analogous to those previously described. Cats 11 and 12, in which depression in conditioned reflex activity appeared by the 10 - 11th week of exposure to low mercury concentrations, received unithiol between the 84 - 98th day of exposure. 220 mg/kg was given subcutaneously daily for a total dose of 600 mg/Kg.

This introduction of active -SH groups led to the recovery (normalization) of lost conditioned reflexes and differentiation. Analogous changes were observed by Sh.A. Galoyan (1959) and N. M. Kostygov (1959) upon the administration of thiol compounds to animals with disturbed conditioned reflex activity caused by mercury dichloride. The thiol compounds were mercaptomber acid, cysteine and unithiol. Other short term experiments also indicate the reversibility of
conditioned reflex damage by restoration of blocked -SH groups. During prolonged exposure, before unithiol, the latent period of conditioned reflexes lengthens, differentiation is initially released and then "strengthened", and response to corresponding signals becomes inadequate to strong stimuli. Then after the introduction of active SH- groups motor-feeding conditioned reflexes normalize comparatively quickly and, in the subsequent (concluding) period of the experiment, do not change, despite prolongation of exposure.

These observations are confirmed by our work along with M. M. Gimadeyev (1963) on -SH determination in the tissue proteins. Decrease in SH- group content of tissue proteins precedes changes in conditioned reflex activity.

Conditioned reflex activity changes in animals affected by low mercury concentrations mimic the early symptoms of micromercurialism. However, they appear after depression of SH- groups. Not only in the analysis of experimental micromercurialism, but also in the study of the toxicology of a series of other (differing in character and action mechanism) toxic substances studied in our laboratory, that specific biochemical response to a given poison is often displayed before the onset of disorders in higher nervous activity. Thus, studies of (V. S. Burry, 1959) involving toxicological evaluation of organophosphorus (octaniethyl) poisoning showed that higher nervous activity changes in test cats set in significantly later than the primary specific response - cholinesterase activity inhibition in the blood.

In analyzing conditioned reflex shifts produced by low concentrations of toxic substances, it is especially important to compare registering functional changes with the dynamics of the respective bio-chemical shifts.

The basic effect of mercury on higher nervous centers lies in its specific mechanism: reaction with SH- groups of cell proteins. Sh. A. Galoyan's (1959), N. M. Kostygov's (1959) and our experiments reflect this. On a background of increasing conditioned reflex disruption caused by mercury, experimental cats were given unithiol, causing normalization of reflex and differentiation functions.
Previous experiments involving experimental intoxication by mercury dichloride and our chronic experiments which approached real production circumstances as closely as possible (daily six-hour exposure to mercury vapor approaching maximum permitted levels), showed the reversibility of disruptions of conditioned reflex activity in animals subjected to mercury by restoration of blocked SH- groups.

These experiments also showed that introduction of unithiol restored conditioned reflex activity even when it had completely disappeared.

Certain data merits attention reflecting the presence or absence of suppression of condition reflex activity in test animals in relation to the amount of active concentration and form in which mercury enters the body. Our observations showed mercury (as a vapor) affects test animals and changed conditioned reflexes and differentiation in differing periods - from the beginning of the experiment (depending on its aerial concentration) - in all cases. However, Sh.A. Galoyan, using mercury dichloride, observed conditioned reflex inhibition in test rats only upon the poisoning of the animals by large amounts of mercury.

A comparison of Sh. A. Galoyan's (1959) data on the mercury content in brain tissue with our analogous data on mercury content of organs showed a "topography" (distribution) of mercury in organs in which mercury dichloride deposits primarily in parenchymatous organs and the lungs, to a much lesser extent in the brain. According to our data, in 100 g of brain tissue after the administration of mercury dichloride, there was 0.88 mg Hg, and Sh. A. Galoyan found even less.

Sh. A. Galoyan found that conditioned reflexes disappeared when only 0.15 mg Hg/100g tissue was present causing a blockage of 0.1 -0.2% of all free SH-
groups. One can suppose, after reviewing data on cats subjected to metallic mercury vapor, that mercury would be present in higher amounts than in the administration of mercury dichloride and consequently, would block more brain tissue SH- groups.

Neither we nor Sh. A. Gaboyan were ready to confirm that accumulation of mercury in brain tissue and the consequent depression of free SH- groups was the only reason for disruption of conditioned reflex activity. Possibly a great role is played by the reaction of mercury with thiol groups of enzyme proteins and the inactivation (during biological processes) of reversible transformations of organ and tissue functions. Low mercury concentrations sharply reduce the number of free -SH groups in the blood, liver and certain other organs and builds up significantly in many organs and tissues.

Upon introduction into the animal organism of equal (by mercury) quantities of ethylmercury compounds, mercury dichloride and mercury vapor, the blood of these animals circulated less mercury and less was excreted in comparison with animals subjected to the action of mercury vapor. Of greatest interest from the point of
view of analysis of the dependence of conditioned reflex activity disruption on the degree of mercury accumulation in brain tissue is our observation that the largest amounts occurred in animals poisoned by ethylmercuric phosphate and ethylmercuric chloride (Table 214).

Figure 31

<table>
<thead>
<tr>
<th>CONDITIONED REFLEX ACTIVITY CHANGES IN CAT 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIL PRIMING</td>
</tr>
<tr>
<td>TIME IN SECONDS</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>UNIL PRIMING</td>
</tr>
<tr>
<td>TIME AFTER PRIMING (in weeks)</td>
</tr>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

Table 25 and Figure 33 show the results of mercury compounds effects on animals affected via the respiratory tract.

Our results correspond with those of A. Swensson (1959) who showed that organomercuricals were retained longer in the brain than in other organs.

The accumulation of mercury in brain tissue corresponds with definite morphological changes in it which will be discussed in one of the following chapters. As a rule, these changes are characterized by mildly pronounced hemodynamic and dystrophic changes. We and V. N. Kurnasov (1962) observed lightening and vacuolization in the pyramidal cells of the cortex. These and other morphological changes appeared in most animals during prolonged mercury exposure without cell destruction. In animals affected by ethylmercury compounds, the higher concentrations produced more pronounced changes such as noticeable dystrophy, sometimes non-reversible (sclerosis of neural elements, karyocytosis) and marked hemo-dynamic disorders.
In conclusion, we will review the facts proceeding from the data herein discussed. First - there is progressive alteration in conditioned reflex activity under exposure to mercury at or slightly less than 0.01 mg/m³. The data obtained in cats agrees with analogous observations of M.M. Gimadeyev (1955) in rabbits and V.N. Kurnosov (1962) in white rats. In the latter case, the disruption of higher nervous activity in test animals arose in a longer experiment (to 9.5 months) at an aerial mercury concentration of 0.002 - 0.005 mg/m³, that is, 2 - 5 times lower than the maximum permissible concentration for industrial sites. It is very significant that at such insignificant levels mercury is detectable in brain tissue in "increased" amounts according to V. N. Kurnosov, (from 0.006 - 0.02 mg/100g tissue).

The second item is that changes in higher nervous activity produced by chemicals varying in action mechanism on cranial processes, can be normalized by restoration of the active SH- group content. This recalls the reversible nature of conditioned reflex activity caused by SB- group blockage and the significance to normal cortical processes of biochemical transformations in which thiol compounds participate.

**Figure 32**

**CONDITIONED REFLEX ACTIVITY CHANGES IN CAT 8.**

<table>
<thead>
<tr>
<th>WEEKS FROM BEGINNING OF PRIMING</th>
<th>TIME AFTER PRIMING (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
</tr>
</tbody>
</table>

- Latent period in white light
- Boundary time in white light
- Latent period to buzzer
- Boundary time to buzzer
- Absence of reaction to blue light
- Release of differentiation
- Extinction of specific conditioned reflexes
### Table 24

Comparative Data on Mercury Content in Guinea Pig Brain Tissue After Exposure to the Effects of Metallic Mercury and Ethyl-Compound Vapors

<table>
<thead>
<tr>
<th>Substance studied</th>
<th>Duration of experiment in days</th>
<th>Average aerosol concentration (mg/kg/m³)</th>
<th>Outcome</th>
<th>Mercury content in brain tissue (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallic mercury</td>
<td>31</td>
<td>2.0</td>
<td>Killed on the 32nd day</td>
<td>0.5</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>2.0</td>
<td>Ditto</td>
<td>1.1</td>
</tr>
<tr>
<td>Ditto</td>
<td>22</td>
<td>2.5</td>
<td>Ditto</td>
<td>0.9</td>
</tr>
<tr>
<td>Ditto</td>
<td>22</td>
<td>2.3</td>
<td>Killed on the 23rd day</td>
<td>1.0</td>
</tr>
<tr>
<td>Ditto</td>
<td>22</td>
<td>2.5</td>
<td>Ditto</td>
<td>0.9</td>
</tr>
<tr>
<td>Ditto</td>
<td>22</td>
<td>2.3</td>
<td>Ditto</td>
<td>2.0</td>
</tr>
<tr>
<td>Ethylmercuric chloride</td>
<td>31</td>
<td>1.6</td>
<td>Killed on the 32nd day</td>
<td>20.9</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>1.6</td>
<td>Died on the 30th day</td>
<td>21.7</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>1.6</td>
<td>Killed on the 32nd day</td>
<td>19.9</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>1.6</td>
<td>Ditto</td>
<td>21.9</td>
</tr>
<tr>
<td>Ditto</td>
<td>21</td>
<td>3.0</td>
<td>Killed on the 23rd day</td>
<td>19.4</td>
</tr>
<tr>
<td>Ditto</td>
<td>21</td>
<td>3.0</td>
<td>Died after 20 days</td>
<td>20.3</td>
</tr>
<tr>
<td>Ditto</td>
<td>21</td>
<td>3.0</td>
<td>Died on the 21st day</td>
<td>21.0</td>
</tr>
<tr>
<td>Ethylmercuric phosphate</td>
<td>31</td>
<td>2.0</td>
<td>Died on the 30th day</td>
<td>19.1</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>2.0</td>
<td>Ditto</td>
<td>18.8</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>2.0</td>
<td>Ditto</td>
<td>19.5</td>
</tr>
<tr>
<td>Ditto</td>
<td>31</td>
<td>2.0</td>
<td>Ditto</td>
<td>17.9</td>
</tr>
</tbody>
</table>

### Table 25

Comparative Data on Hg Content in Rabbit Brain Tissue After Mercury Dichloride and Ethylmercury Compound Poisoning

<table>
<thead>
<tr>
<th>Substance Studied</th>
<th>Dose of preparation injected (in mg Hg to body weight)</th>
<th>Duration of experiment (in days)</th>
<th>Outcome</th>
<th>Mercury content in brain tissue (in mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury dichloride</td>
<td>10</td>
<td>15</td>
<td>Killed on 16th day from start of experiment</td>
<td>2.5</td>
</tr>
<tr>
<td>Ditto</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>2.4</td>
</tr>
<tr>
<td>Ditto</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>2.0</td>
</tr>
<tr>
<td>Ethylmercuric chloride</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>24.5</td>
</tr>
<tr>
<td>Ditto</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>25.0</td>
</tr>
<tr>
<td>Ditto</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>24.0</td>
</tr>
<tr>
<td>Ethylmercuric phosphate</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>20.0</td>
</tr>
<tr>
<td>Ditto</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>20.0</td>
</tr>
<tr>
<td>Ditto</td>
<td>10</td>
<td>15</td>
<td>Ditto</td>
<td>26.0</td>
</tr>
</tbody>
</table>
CHAPTER X

FUNCTIONAL SHIFTS IN THE HYPOPHYSEAL ADRENOCORPICAL SYSTEM and the Thyroid Gland Under the Influence of Mercury

It is known that I. P. Pavlov repeatedly pointed to endocrine regulation as one of the powerful actuators by which the CNS accomplishes its integrating and correlating role. The leading significance of the latter in the realization of these or other hormonal functions is broadly indicated in a series of Soviet publications on the problems of the pathophysiological and clinical analysis of the state of endocrine function in various pathological processes - inflammatory, infectious, etc. Simultaneously problems of functional disturbance and of endocrine gland regulation under toxic effect falls essentially into the purview of endocrinologists. Additionally, many practical and experimental observations, undertaken in this direction at hygiene and toxicological laboratories indicate that the endocrine system is very sensitive to the action of various toxic substances.


Our experiments are based on these works. First of all, note the absence in the literature of experimental data referring to functional changes in the adrenal and thyroid glands under prolonged exposure to mercury at or about the maximum permissible levels, and contradictory data on the effect of mercury on the thyroid gland. Thus, at the same time that some authors (R. N. Vol'f dovskaya, 1928; M. A. Kazakevich, 1933; Ya. Z. Matushevich and L. M. Frumina, 19314.; A. M. Monayenkova, 1958) detected hyperthyroidism in persons working with mercury, some of these investigators, primarily foreign (G. Baldi, 1911.9; P. Neal, B. Jones, 1938, et al) did not detect the indicated changes. Let us remember that, in the process of examining persons, having contacts with minimal amounts of mercury we found symptoms of thyroid dysfunction, indicated in many by the increased glandular retention of radioactive iodine.
Deepening investigation into the effect of mercury on the endocrine glands required experiments designed to discern low intensity toxic action. Equally significant is discovering the linkage between non-specific shifts in a series of endocrine functions with the specific genesis of various (by toxin action mechanism) toxic disorders. Beside its theoretical application to microniercurialism problems, it is important to determine the significant functional disorders of the hypophyseal-adrenal cortical and thyroid system in the pathogenesis and diagnosis of latent toxic effect.

On the one hand, the actual effect of low mercury concentrations on the hypophyseal-adrenal cortical system must be determined, on the other - in cases of the absence or presence of functional shifts in this system - its character and features in relation to age.

This study is of interest primarily because of the adrenalinhypophyseal role in adaptation mechanisms, primarily functioning as regulators and coordinators of multiple CNS body functions. The observations of I. P. Pavlov and his school, L. A. Orbeli, on the adaptive-trophic effect of the nervous system, the investigations of A.D. Speranskiy, studies of the role of the sympatho-adrenal system, etc., make it impossible to agree with the widely accepted view of H. Selye (1956) about the general adaptive syndrome. It is known that the hypophyseal-adrenal cortical system plays an important role in the realization of the syndrome, but we feel that it is only one of several features of multiple adaptive mechanisms present in the organism. The incorrectness of H. Selye's position lies in its premise of the first mediator of stress (tension response). He gives insufficient weight to the CNS role as one of the basic "trigger" mechanisms, determining the adrenal-hypophyseal reaction.

This position was taken by us after analysis and interpretation of data on the effect of mercury on the hypophyseal-adrenal cortical system. Below is presented data obtained in experiments on rats.

Analysis of literature data on the relative ascorbic acid content (AA) in white rat adrenals indicates that its glandular content varies within significant limits. In the first series of experiments we could demonstrate the excessive variability of this indicator. In healthy rats of one age in analogous circumstances (nutrition, etc.), the adrenal -AA content in one group was 296 - 521 mg%, in a second group, 390 - 691 mg%, in a third, 251 - 485 mg%. Prolonged action of low mercury concentrations depress the adrenal AA content. Differences in average quantities were statistically significant at the eighth (5 - 7 month rats), and fifteenth (18 -20 month rats)week from the start of the experiment. Insignificant differences occurred during the first 4 - 6 weeks (5 - 7 month rats) and first 5 - 9 weeks (18 - 20 month rats).

Note the difference in dynamics at the two ages. In old rats (18 - 20 months), there was less AA depression and it appeared later than in younger rats (5 - 7 months). The dynamics of ascorbic acid content in the adrenals of experimental and control animals is shown in Figure 34.

Increase in the weight of the gland is not as definitive as the AA content change. There was a tendency towards maintenance in the older rats (more marked changes in the 5 - 7 month rats) where gland weight changes appeared later and were not as highly developed. Low mercury concentrations produced comparatively little change in AA levels and agrees with the results of E. I. Spyna (1959) who found that low concentrations of substances produced functional activity changes in the adrenals without noticable gland hypertrophy.

Increased adrenal activity in rats and white mice subjected to water stress was confirmed in experiments on animals subjected daily (6 hours) to 0.006 - 0.01 mg/m3 Hg for 145 days.

Our data showed that the control animals excreted 69% of injected water within five hours. Mice exposed to mercury for 90 days excreted 63% of the water in this time. Further diuretic decrease was statistically significant from the 112 - 145th day of the experiment.
Low mercury concentrations increase the functional activity of the hypophyseal-adrenal cortical system markedly in young animals and to a lesser degree in older animals.

Figure 34

ASCORBIC ACID CONTENT IN ADRENALES OF EXPERIMENTAL AND CONTROL RATS OF DIFFERENT AGES

RATS 5-7 MONTHS OLD

RATS 18-20 MONTHS OLD

Test results are presented in Table 26.

<table>
<thead>
<tr>
<th>Time of study</th>
<th>2 hours</th>
<th>6 hours</th>
<th>12 hours</th>
<th>24 hours</th>
<th>48 hours</th>
<th>72 hours</th>
<th>96 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic data</td>
<td>11.44%</td>
<td>16.27%</td>
<td>18.27%</td>
<td>26.12%</td>
<td>23.67%</td>
<td>20.92%</td>
<td>19.17%</td>
</tr>
<tr>
<td>After 7 days</td>
<td>10.72%</td>
<td>14.47%</td>
<td>19.92%</td>
<td>29.62%</td>
<td>25.92%</td>
<td>20.92%</td>
<td>15.32%</td>
</tr>
</tbody>
</table>

TABLE 26

Uptake Intensity of Radioactive Iodine by the Thyroid Gland In Experimental and Control Rats by 7 Days From the Start of the Experiment (First Series)

<table>
<thead>
<tr>
<th>Group of animals</th>
<th>Number</th>
<th>Time of study</th>
<th>2 hours</th>
<th>6 hours</th>
<th>12 hours</th>
<th>24 hours</th>
<th>48 hours</th>
<th>72 hours</th>
<th>96 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>30</td>
<td>Basic data</td>
<td>11.44%</td>
<td>16.27%</td>
<td>18.27%</td>
<td>26.12%</td>
<td>23.67%</td>
<td>20.92%</td>
<td>19.17%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After 7 days</td>
<td>10.72%</td>
<td>14.47%</td>
<td>19.92%</td>
<td>29.62%</td>
<td>25.92%</td>
<td>20.92%</td>
<td>15.32%</td>
</tr>
<tr>
<td>Controls</td>
<td>20</td>
<td>Basic data</td>
<td>11.25%</td>
<td>13.23%</td>
<td>18.23%</td>
<td>22.13%</td>
<td>22.02%</td>
<td>20.12%</td>
<td>17.32%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>After 7 days</td>
<td>12.43%</td>
<td>16.31%</td>
<td>17.31%</td>
<td>23.23%</td>
<td>21.31%</td>
<td>18.31%</td>
<td>16.92%</td>
</tr>
</tbody>
</table>

On the one hand this data indicates the high sensitivity of the hypophyseal-adrenal cortical system to low intensity effects, at which external signs of toxicosis would not have yet appeared, and on the other hand the relation of age to toxic effect (compensation possibilities).

Thus there is a tight bond between adrenal and thyroid function pointed out by S. C. Werner, 1955; W. L. Money, 1963. Thyroid dysfunction can indicate hypophyseal-adrenal disorder.

Materials presented below are results of five series of experiments on the analysis of low mercury concentration effects on thyroid function of test animals under various exposure conditions. Data is presented in Table 26.
After longer exposure (30 days), increased thyroid function was clear. In controls, maximum isotope uptake appeared by the 24th hour (20 - 30%) and in test animals, within 6 - 12 hours (also 20 -30%). Radioactive iodine uptake is more rapid in test rats; by the 96th hour the glands of test rats retained 15.6% of the isotope (from a 41.2% maximum) while the controls retained 18.3% (from a 25.1% maximum). These uptake figures (for controls) are characteristic of those for hyperthyroidism.

**TABLE 27**

Uptake Intensity of Radioactive Iodine by the Thyroid Gland in Experimental White Rats (Second Series)

<table>
<thead>
<tr>
<th>Time after injection of I131</th>
<th>Basic Data</th>
<th>After one month</th>
<th>After 71 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hours</td>
<td>15.6±0.6</td>
<td>25.3±1.9</td>
<td>37.1±3.1</td>
</tr>
<tr>
<td>12 hours</td>
<td>21.9±1.4</td>
<td>41.2±3.8</td>
<td>83.2±7.9</td>
</tr>
<tr>
<td>24 hours</td>
<td>37.0±1.1</td>
<td>37.8±4.1</td>
<td>78.1±8.1</td>
</tr>
<tr>
<td>48 hours</td>
<td>27.8±2.1</td>
<td>30.3±3.2</td>
<td>52.2±6.0</td>
</tr>
</tbody>
</table>

Further increase in length of mercury effect led to even more pronounced changes in radioactive iodine (I131) uptake (Table 27).

After 50 days of exposure to mercury, the I131 uptake after 2 hours was 15.13%, after 12 hours - 58.3%, after 24 hours - 50.0%. Before the experiment the figures were: After 2 hours - 10.5%, after 12 hours - 16.1%, after 24 hours - 22.14%, with a maximum reached after 24 hours, which in the experiment itself the maximum was reached in the first 6 - 12 hours. Control figures remained constant. In the second group, examined after 67 days exposure, glandular hyperfunction also appeared.

In the third series in which the animals were exposed to 0.01 -0.03 ing Hg/m3, there was clear evidence of the character and degree of glandular changes brought on by low mercury concentrations. In test animals before the experiment glandular isotope uptake after two hours was 15.6%, after 12 hours - 21.8%, after 214. hours - 28.96%, and after 48 hours - 26.14% with a maximum by the 214 hours. After 87 days of exposure, 32.7% uptake had occurred within 2 hours of isotope injection. Glandular activity increased sharply reaching a maximum by 4 - 6 hours after which it dropped relatively quickly. After 48 hours isotope uptake was 51.1% of the injected quantity.

Even more marked changes occurred when exposure time was increased to 105 days. Data from the experiment is shown in Table 28.

From the table it is evident that maximum iodine uptake in test animals occurs significantly earlier and the uptake rate is greater than in controls. Gas
metabolism did not change significantly during this period (before - 1702 ml/hr/Kg; after AA - 3 months - 1794 ml/hr/Kg).

<table>
<thead>
<tr>
<th>Time after injection of 131I</th>
<th>Basic data</th>
<th>After one month</th>
<th>After five months</th>
<th>After administration of unithiol (in seventh month of experiment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hours</td>
<td>10.03±0.6</td>
<td>25.2±1.0</td>
<td>40.7±3.5</td>
<td>10.5±0.3</td>
</tr>
<tr>
<td>6 hours</td>
<td>11.4±0.8</td>
<td>31.9±2.3</td>
<td>72.3±7.1</td>
<td>21.5±1.8</td>
</tr>
<tr>
<td>12 hours</td>
<td>15.6±1.0</td>
<td>42.3±4.1</td>
<td>69.7±6.8</td>
<td>14.9±0.9</td>
</tr>
<tr>
<td>24 hours</td>
<td>17.4±1.2</td>
<td>31.9±3.6</td>
<td>50.4±4.2</td>
<td>18.4±1.2</td>
</tr>
<tr>
<td>48 hours</td>
<td>22.2±1.3</td>
<td>17.6±1.9</td>
<td>20.6±1.6</td>
<td>18.2±2.0</td>
</tr>
<tr>
<td>72 hours</td>
<td>20.0±1.4</td>
<td>25.3±1.7</td>
<td>31.4±3.6</td>
<td>21.3±1.8</td>
</tr>
<tr>
<td>96 hours</td>
<td>21.8±1.0</td>
<td>19.5±1.3</td>
<td>19.7±1.4</td>
<td>17.1±1.6</td>
</tr>
</tbody>
</table>

**TABLE 29**

Radioactive Iodine Uptake in the Thyroid Gland of Experimental Rats Before and After Unithiol Injection (Fourth Series)

<table>
<thead>
<tr>
<th>Time after injection of 131I</th>
<th>Basic data</th>
<th>After one month</th>
<th>After five months</th>
<th>After administration of unithiol (in seventh month of experiment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hours</td>
<td>13.7±2.1</td>
<td>11.3±0.6</td>
<td>11.2±0.6</td>
<td>10.4±0.9</td>
</tr>
<tr>
<td>6 hours</td>
<td>13.9±1.0</td>
<td>16.3±1.9</td>
<td>15.3±1.6</td>
<td>13.1±1.4</td>
</tr>
<tr>
<td>12 hours</td>
<td>18.5±1.2</td>
<td>20.8±1.4</td>
<td>19.8±1.7</td>
<td>18.1±1.8</td>
</tr>
<tr>
<td>24 hours</td>
<td>22.1±1.6</td>
<td>28.4±2.0</td>
<td>24.8±1.5</td>
<td>21.3±1.1</td>
</tr>
<tr>
<td>48 hours</td>
<td>22.0±1.3</td>
<td>24.9±1.5</td>
<td>22.3±2.0</td>
<td>23.9±1.2</td>
</tr>
<tr>
<td>72 hours</td>
<td>20.1±1.4</td>
<td>20.4±1.7</td>
<td>20.6±1.7</td>
<td>19.9±1.7</td>
</tr>
<tr>
<td>96 hours</td>
<td>19.5±1.3</td>
<td>18.6±1.6</td>
<td>18.3±0.8</td>
<td>16.7±1.3</td>
</tr>
</tbody>
</table>

**TABLE 30**

Radioactive Iodine Uptake by Thyroid Glands of Control Rats Before and After Introduction of Unithiol (Fourth Series)

We then analyzed the possibility of normalizing thyroid function after exposure by antidotes which prevent further toxic effects and accelerate mercury excretion. The results of four series of experiments on two groups of animals
Exposed to low mercury concentrations, after which unithiol was given (200 mg/Kg for 3 days) are shown in Tables 29 and 30.

Unithiol normalizes thyroid function; maximum isotope uptake time is prolonged to 24 hours; the maximum 131I quantity in the gland decreases to 21.5% and excretion rate approaches that of the control animals.

Analogous results from the fifth experimental series are shown in Table 31.

Thus, the functional activity change of the thyroid gland under the effect of small mercury concentrations is reversible upon the addition of free SH- groups and normalizes fairly quickly.

Such functional dynamics have also been shown by N. A. Gabelova, 1953; M. N. Fateyeva, 1953; F. H. Keating, 1949, etc.

It is possible to suggest that mercury reacts with SH- groups of tissue proteins, blocking thyroglobulin even in small amounts. "Hormonal insufficiency" appears, stimulates increased glandular hormone synthesis, stimulating compensatory response to the hypophysis and other mechanisms, regulating the activity of this organ.

This gives a partial explanation of the non-appearance of evidence of thyrotoxicosis although this does not exclude the possibility of later development of specific symptoms. In fact these are often observed in clinics as one of the signs of micromercurialism (M.A. Kazakevich, 1945; H. N. Vol'fovskaya, 1925). Thyrotoxicosis has been observed in persons who have had prolonged contact with low mercury concentrations (Ya. Z. Matushevich, I. M. Frumina, 1934).

Experimental and clinical data discussed above permit us to state that low mercury concentrations produce hormonal shifts and thyroid dysfunction. This data is of special interest from the point of view of changes arising in micromercurialism. They can be used in the early diagnosis of the effects of low mercury concentrations on the organism.

CHAPTER XI

CARDIOTOXIC EFFECTS OF MERCURY

Recently definite factual materials have accumulated which indicate that thiol poisons influence metabolism and function in various parts of the self-regulation system. Thiol poisons affect several aspects of cardiac activity, mediatory and extra-cardiac nerve activity, myocardial contractility and electrical activity, etc.

The interoceptive apparatus of the heart and vessels are highly sensitive to the action of even low intensity chemical factors.

V. N. Chernigovskiy (1949) found that chemoreceptors are related to tissue receptors. In other words, they "intercept" shifts not only in blood chemistry, but in tissue metabolism of substances. This is why changes in tissue trophics develop frequently as a consequence of enzyme reactions affected by thiol poisons, including mercury, which are complex irritants of chemoreceptors. Additionally, toxic substances blocking thiol enzyme systems, alter the metabolism of the nerve endings themselves (Kh. S. Koshtoyants, 1945, S. V. Anichkov, 1953, M. L. Belen'kiy, 1951, V. N. Chernigovskiy, 1949).

Changes arising in parts of the cardiovascular system are heterogeneous and vary in significance. Additionally, they are closely interwoven.

The self-regulating function is explained in that changes in one part can lead to shifts in the entire system. One and the same type of hemodynamic disorder can be the result of various interactions, arising in the blood circulation system. That is why analysis of cardiovascular changes caused by the effect of
low mercury concentrations must involve study of shifts in different parts of the blood circulation system.

Chapter Six presented data on the frequency and character of functional cardiovascular disorders in persons having contact with low mercury concentrations. Analysis of this data showed that among those subjected to prolonged exposure to mercury vapor under industrial conditions there was an increased number of cardiac ailments, and a high percentage of arterial hypotension.

First, one has to clarify the change characteristics of a series of cardiac activity functional indicators under chronic exposure to animals to low mercury concentrations; secondly, of primary importance regarding cardiac function, is answering the question of whether low intensity toxic action affects the reactivity of one or another system, its character, its corresponding reactions with other "non-toxic" agents. Generally mercury affects the myocardium adversely and common physiological disorders, of a borderline nature, become the basis of one or another pathological shift. Thus, it is interesting to note the response changes of the cardiovascular system, affected by mercury, to pituitrin injection. Under normal conditions pituitrin plays an important role in the development of coronary insufficiency in man.

Electrocardiographic studies made at the beginning of exposure, and then after 16 - 95 days (first series) and 90 - 329 days (second series). In the latter case electrocardiograms (EKG) were taken during the simultaneous modeling of coronary insufficiency and measured three standard responses. The results were compared with initial quantities and also with analogous electrocardiographic data taken from healthy rabbits (A. O. Saytanov, 1960). First of all we noted the absence of any EKG indicator changes before the beginning of the experiment (basic data). In all cases experimental rabbits had normal EKG' s with a predominance of the right hand type of distribution of the electric axis. During the first 3-4 weeks thereafter the EKG' s remained unchanged. Then tachycardia, and diminished cardiac contraction frequency was noted. By the third month all test rabbits had developed pronounced bradycardia in which the heart rate of the majority of animals did not exceed 220 - 250 beats per minute. Changes were characterized by lowering and broadening of P voltage waves. In the ventricular complex there was a decrease in R and T voltage waves and in some cases, displacement of the ST interval.

The most noticeable changes were in beat frequency and voltage. Thus, by the end of the second month the cardiac contraction rhythm reached a maximum -- 310/mm. By the 70th day it had decreased to 252/mm (marked bradycardia). Notable changes occurred in P voltage, from an average of 0.12 my it had decreased to 0.05 my by the 70th day. R Voltage showed a definite change from 0.36 my to 0.24 my by the end of the experiment. A more significant diminution occurred in S voltage from an average initial 0.21 my to 0.09 my by the end of the experiment. T went from 0.25 my to 0.17 my.

Under chronic mercury exposure rabbit EKG's exhibited a progressive voltage decrease.

Less considerable but sufficiently stable (noted in all rabbits) were changed in duration of specific EKG components. Thus the duration of the QP complex and QT interval was almost unchanged. There was only an insignificant increase in the length of tooth P and interval PQ.

Especially indicative and noteworthy is that, in the process of mercury action there was a change in form and direction of separate EKG segments. Interval ST, as a rule, shifts above the isoelectric line while T waves decrease and broaden. Analysis of separate EKG's from test rabbits in our and A. O. Saytonov's work, showed that, in healthy rabbits along with changes in the initial and final parts of the EKG, its component rate did not undergo notable change.

There were important individual variations in the type of cardiac activity change in each animal. Along with changes appearing in a significant group of animals at a relatively early stage of mercury effect, only the electrical
activity of the heart changed somewhat by the 60 - 75 day in some rabbits. Toward the end of the experiment P, R and T voltages decreased (P in 15 of 24 cases, R and T in 12).

In 9 of 14 cases, the ST interval shifted with respect to the isoelectric line (The steadiest character was shown in cardiac activity rhythm changes. In all cases bradycardia had appeared by the end of the experiment.

The data shown by the EKG of rabbit 9 indicates different sensitivities and responses as compared to data from rabbit 12. Rabbit 9 showed more pronounced changes even though the exposure time for rabbit 12 was greater.

Low concentrations of mercury, after a short, apparently beneficial period, produce a series of EKG shifts, repeating regularly and monotypically in all experiments.

Phase and rhythmic changes in cardiac activity are not specific for mercury effects. Currently, facts have accumulated indicating that various pharmacological and toxicological agents and also a series of infectious diseases produce biphasic alterations in cardiac activity rhythms. Analysis of the relationships and character of these phases in light of concepts of specific tissue response to irritant action, especially to N. Ye. Vvedenskiy's concept of parabiosis, allows one to link them with biphasic changes in the lability of the substrate itself -- the heart and the tonus of regulating centers of this system -- the vagus and sympathetic nerves. In this connection special interest is shown in the data of I. A. Arshavskiy, et al (1956) which concluded from the analysis of data on excised extracardiac nerves, that cardiac rhythm changes under the influence of various toxic substances, are usually toward slowing the rhythm and is connected with changes in tonus of the vagus nerve.

in postulating the "universal" character of phases in cardiac rhythm changes, one can state that this phasicity is closely linked to, and is part of, changes developing in general neurodynamics characteristic of CNS changes in micromercurialism. Thus, the tendency to tachycardia, as a rule, corresponding to the hypersthenic form of the astheno-vegetative syndrome, occurs in the initial stages of micromercurialism with a predominance in the cerebral cortex of activation processes and increased tonus of the sympathetic nervous system, and bradycardia develops after longer exposure with a predominance of inhibition and increased tonus of the vague nerve.

These responses apply not only to mercury but are nonspecific in their genesis. Evidently in certain types of changes in the activity of a given organ, such as the heart, lie a complete and definitive biochemical dynamics.

As stated above, the reaction of tissue protein SH- groups is important in the mercury action mechanism.

Currently, many facts have accumulated indicating that cardiac function usually depends on cholinoreceptor properties. The vague nerve endings contain acetylcholine having a highly specific effect on the heart muscle which incorporates cholinoreceptors-proteins, the active principle of which are SH-groups. The SH-group reaction capacity is affected by mercury and can change aspects of acetylcholine formation and tissue response to it. That is why we can conclude that the mercury effects produce specific shifts both in the biochemical dynamics of the cardiac muscle and in its response, despite the latter displaying (in origin and course) "nonspecific" type reactions.

The experiments of B. N. Manukh and R. L. Mitropolitanskaya (1959) showed that mercury dihydrochloride lowered cardiac sensitivity to acetylcholine and vague nerve influence.

In mammals exposed to the action of certain concentrations of substances blocking SH-groups, the heart ceases to respond to the vague nerve. Response can be restored by subsequent administration of substances containing active SH-groups.
Thus far, investigators have studied primarily peripheral effects. Upon the administration of thiol poisons, functional changes occur in centers regulating cardiac activity. It is interesting in this respect to analyze one seeming contradiction. Experimental data indicates that mercury and other toxic substances reacting with SH-groups lower cardiac sensitivity to the vague nerve while clinical and experimental observations indicate the development of bradycardia during mercury exposure.

In lability changes of the heart and contractile rhythm under the influence of mercury a determining role is played not only by changes in SH-group reactivity of the myocardium itself, that is in its receptivity to vagal influence, but of changes in the tonic effects of centers of this nerve. Under chronic mercury effect, there are a series of functional changes in the cardiovascular system with a predominance of the tonic influence of the parasympathetic system. One of these changes is the development of arterial hypotension. Thus, from two types of effectors -- cardiac and vascular, there appears one type of directional change in extracardiac neural influence -- bradycardia and hypotension, at the base of which lies one mechanism -- tonic changes of parasympathetic innervation. The presence during this of symptoms of myocardial damage of the ventricles (alteration of the ST-interval and changes in T waves) indicates simultaneous vagus effects and continuous toxic action on the heart. Clinical observations of N. S. Lashchenko (1965) on the course and features of organomercurial cardiotoxic effects confirm this.

Changes in heart action under the influence of mercury, evidently, is much connected with mercury's direct action on the heart itself and on its metabolism of substances. In some experiments there was a divergence between the degree of development of the extra-cardiac effect, as, for example, bradycardia and the degree of shift in other EKG components, especially in the final part -- of the ST, interval and R and T peaks. Pathomorphological data, to be discussed in the following chapter, confirms this. Changes followed in animals exposed to low mercury concentrations included granular dystrophy of the myocardium, dystrophic changes in the capillary endothelium (desquamation and swelling), disorders in
coronary blood formation. Our experiments showed that the heart is a notable mercury depot.

Functional disturbance in the myocardium is a consequence of disruption of extracardiac heart activity regulation as a result of the continuous toxic effect of mercury on the myocardium and heart valves, primarily through SH-group blockage. T. M. Turpayev (1950) proposed that "suppression of the contractile properties of the myocardium through the action of thiol poisons occurring as a consequence of SH-enzyme inactivation is directly linked with the energetic contractile act of the myocardium."

Thus, under the effects of low mercury concentrations during daily mammalian exposure to it, the heart develops definite functional shifts. Under further toxic effect, these shifts continue and take on a more developed character. In the developmental stages of the cardio-toxic effect when the shifts present are still insignificant, one can detect the presence of cardiac reactivity (sensitivity) to the action of factors affecting its function and the course of metabolic processes. Verification of the premise has great significance for understanding the effect on the organism of low intensity toxic actions, and also from the position of clarification and analysis of those latent "prepathological" shifts, which precede the development of intoxication. From this standpoint it is vital to explain whether there is and, if so, to what degree reactivity change in the myocardium affected by mercury effects the appearance of acute coronary insufficiency.

It is known that pituitrin contains several active principles, oxytocin, vasopressin and antidiuretic homones. The active principle involved in the production of experimental coronary insufficiency is vasopressin. Currently, interest in the experimental model produced by intravenous injection of pituitrin into humans as proposed by A. V. Tonkikh, A. I. Il'ina, S. I. Teplov (1950), vasopressin brings on an attack of acute coronary insufficiency, objectively registering on the EKG - bradycardia, change in the ST segment with respect to the isoelectric line, rising coronary T waves, and deepening of Q wave.

Pituitrin was given to test animals intravenously in 0.15 - 0.3 ml/kg doses (in 1 ml solution, 3 units pituitrin), and caused coronary insufficiency, according to our and other data (V. V. Frol'kis, et al., 1962). EKG changes in rabbits appeared within 9 - 20 seconds, in controls, within 25 - 14.2 seconds. In the latter these changes were noted respectively during 26 - 30 and 114. - 20 minutes.

Bradycardia developed earlier than other changes. After pituitrin introduction, the average beat frequency in the test animals decreased to 114% of the initial amount, when this decrease was 50% in controls. Restoration of rhythm to initial levels occurred after normalization of all other indicators.

On a background of bradycardia, changes which arose in the so-called EKG coronary segment in test animals appeared earlier and were more sharply developed. Reversible development of the indicated changes in test animals occurred later than in controls. After the introduction of pituitrin on the background of mercury effect, T waves often increased, reaching the height of R and assumed a peak-like form. The ST interval shifted sharply upward as a consequence of which T and R waves closed up producing the coronary T-form.

Other changes, less developed and appearing later, occurred. They produce slowing of atrioventricular flow, broaden the QRS complex, diminish Q and S voltage and, as a rule, increase P voltage (it subsequently diminishes). These changes were recorded in all cases in the experimental animals and only in 9 of the 18 controls.

A special demonstration of these differences occur during simultaneous registration of cardiac electrical activity in test and control animals (Figure 37). Parallel EKG component changes were not noted in all cases. In four of the experimental animals there were changes in EKG voltage peaks during abrupt onset of cardiac rhythm activity shifts.
For determination of the degree of cardiovascular activity changes under the influence of mercury, there is special interest in determining threshold pituitrin concentrations producing the first EKG appearance of coronary insufficiency in control and experimental rabbits. Results showed that in test animals coronary insufficiency developed at a lower pituitrin dose than in controls. Thus, at 0.05 ml/kg pituitrin the ST segment changed with respect to the isoelectric line in test animals (Figure 38). In controls this dose did not alter the EKG's appreciably.
The obtained data indicates that, in experimental animals, coronary insufficiency develops at lower pituitrin doses, and changes are more pronounced than in controls.

We obtained some EKG's and data from separate experiments illustrating the differences in coronary spasm development in test and control animals.

In conclusion, let us stress that, in this series of experiments, there was notable variability in individual sensitivity of rabbits to pituitrin. In some cases, the same animal responded differently to separate pituitrin injections while in others response to pituitrin was less marked. However, despite individual variations, in an overwhelming majority of cases in animals subjected to prolonged mercury exposure, EKG shifts were more sharply developed than in control rabbits.

One can speak of the mechanism of growing myocardial hypoxia leading to acute coronary spasm under the influence of pituitrin. On the other hand, coronary vascular spasm might not be developed enough, appearing only under the influence of mercury, but even minor spasms could disrupt myocardial trophics, both factors reflecting in the EKG, and both obviously playing a determining role.

Low intensity toxic effects can make simultaneous background metabolic changes and produce significant circulatory changes. During prolonged exposure to mercury a number of changes in different parts of the self-regulatory functions of the circulatory system occur. Reactivity of cardiac effectors, tonic effects in sympathetic and parasympathetic innervation centers appear. These shifts in interaction of the center and periphery include respective feedback information, thereby establishing a new level of cardiovascular self-regulation.

Currently, much attention is paid to facilitating reactions, compensatory reserve mechanisms of one or another system. Our data shows that prolonged
exposure even to low mercury intensities (about 0.01 mg/m³) limit cardiovascular reactive capability. We feel that this conclusion should have principal significance in general analysis of pathological changes appearing in the organism under the influence of low concentrations of toxic substances.

CHAPTER XII

CHANGES IN INDICES OF IMMUNOBIOLOGICAL REACTIVITY UNDER THE INFLUENCE OF LOW MERCURY CONCENTRATIONS

Can chemical substances, entering the worker respiratory zone under industrial conditions, lead to lowered reactivity of the organism? Is there usually a low intensity toxic effect on the immunological properties of the organism? The answers are of interest from several standpoints. On the one hand, studying the reactivity of the organism affected by chemical factors of the individual environment is important for analysis of so-called nonspecific actions of occupational poisons, on the other hand, such studies touch a circle of problems treating the linkage between character and structure of general ("non-occupational") diseases of workers affected by their every-day production activity and working conditions. Finally, reactivity shifts can be used as one of the pertinent criteria for deriving hygienic norms for the content of harmful chemicals in the air.

Until recently it was considered the immunological reactivity is the specific reactivity, appearing in reactions of the organism in response only to strictly determined irritants of an antigenic character and permits the assessment, at one or another levels, of immunobiological "resistance". Currently, most researchers adhering to modern viewpoints, regard immunobiological reactivity as a more universal reaction, complying with general physiological laws and can serve not only as an indicator of specific resistance but of the general strength of the body. One can state, that "the formation of additional antibody-like structures is an expression of a general bodily response to a foreign substance" (A. A. Zivber, 1962).

It should be emphasized that, in modern immunology, the question of the effect of industrial environmental factors on reactivity has been insufficiently studied. Studies of links between one or another immunobiological reactivity state in workers at industrial sites and the level and character of their ailments have appeared in the works of I. G. Fridlyand, 1959; V. M. Shubik, B. E. Saf'yan, Yu. G. Shubik, 1959; A. I. Pakhomychev, 1960; B. E. Saf'yan and V. M. Shubik, 1960.

Previous investigations of immunological response to such industrial poisons as oxides of: carbon, lead, chlorine; sulfuric anhydride, aniline, nitrobenzene and dichloroethane were made (L. A. Kandyba, Sh. G. Perlina, 1926; Ya. F. Sakhnovskiy, 1926; S. I. Ashbel' et al, 19148; B. A. Kiryachko, 1955; P. A. Semedova, 1957; V.K. Navrotskiy, 1957, et al). There have been no studies until now of the immunobiological effects and immunity reactions of mercury or its derivatives. Therefore, such experimental observations with respect to microniercurialism were extremely necessary.

Results of five series of experiments employing white rats and rabbits are shown in Table 32.

As is evident from Figure 39 and Table 33, most of the animals even by the 30 - 34th day of exposure to 0.006 - 0.01 mg/m³ Hg had a higher percentage of active leucocytes which reached a maximum (44.9%) by the 3-4th month of the experiment. Later, the active leucocytes percent began to drop off sharply. By the 175th day it had decreased to 26.2% from an initial level of 31%. This was not observed in the controls.

There was some increase in the number of active neutrophils - to 10.3% by the end of the experiment.

There were individual animal responses to the indicators. Thus, if the maximum rise in the majority of rats occurred by the 9 - 10th week from the start of the
experiment, then in rats 3, 11, 14, it wasn't noted until the 16th week. In rats 13 and 27 the drop in percent of phagocytes had already occurred by the fifth week of exposure. Despite individual deviations, the general tendency to initial rise and subsequent drop in the indicators studied in the test animals was sufficiently clear.

TABLE 32
Experimental Conditions for the Determining Immunological Indices on a Background of the Prolonged Action of Low Mercury Concentrations

<table>
<thead>
<tr>
<th>Experimental Series</th>
<th>Animal Species</th>
<th>Group of Animals</th>
<th>Exposure</th>
<th>Aerial mercury concentration (mg/m³)</th>
<th>Indicator Studied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Experimental</td>
<td>Daily (in hr.)</td>
<td>Total (in days)</td>
<td>Minimal</td>
</tr>
<tr>
<td>First</td>
<td>White rats</td>
<td>18</td>
<td>6</td>
<td>266</td>
<td>0.007</td>
</tr>
<tr>
<td>Second</td>
<td>Ditto</td>
<td>15</td>
<td>6</td>
<td>157</td>
<td>0.008</td>
</tr>
<tr>
<td>Third</td>
<td>Ditto</td>
<td>22</td>
<td>6</td>
<td>166</td>
<td>0.01</td>
</tr>
<tr>
<td>Fourth</td>
<td>Rabbits</td>
<td>10</td>
<td>6</td>
<td>178</td>
<td>0.01</td>
</tr>
<tr>
<td>Fifth</td>
<td>Ditto**</td>
<td>12</td>
<td>6</td>
<td>394</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>White rats</td>
<td>18</td>
<td>6</td>
<td>175</td>
<td>0.007</td>
</tr>
</tbody>
</table>

* In the fourth series of experiments, the determination of complementary activity of the serum was done in non-immunized rabbits.
** In the fifth series of experiments, the rats were not immunized.

Figure 39
DYNAMICS OF PHAGOCYTIC ACTIVITY OF BLOOD NEUTROPHILS IN EXPERIMENTAL AND CONTROL RATS

The phagocyte figures are shown in Table 34. Here there is a tendency toward diminution seen even at the initial toxic effect which persisted throughout the experiment. Thus, by the third week, the number of phagocytes was 0.78 (controls - 0.81); by the 23rd week it had declined to 0.51 (controls - 0.76), and by the 25th week, to 0.46 (controls - 0.82).
Possibly the diminution in phagocyte number precedes certain elevations in observed number of active phagocytes not herein observed until the end of the third week. As a result of primary immunization of animals subjected to mercury (0.008 - 0.03 mg/m3) the phagocytic number increased 76%. Later each subsequent injection of typhoid fever antigen was accompanied by a notable increase in phagocytic number which occurred initially more intensively than in control animals. Later, after prolonged exposure, the immunizatory effect in the group of test rats began to differ sharply from that in the control group which usually appeared a month after the third immunization and a week after revaccination. Thus, in controls, the phagocytic number before immunization was an average of 0.76; after the first immunization done 60 days after the start of the experiment, it had increased to 0.92; after the second, to 1.35; after the third, to 2.35. After a month, the phagocytic number was 1.71, after revaccination (7th day), 3.99, by the 14th day, 4.26. At the same time the test animal figures were notably higher. Comparative data is shown in Figure 40 and Table 34.

Changes in immunological reactivity brought on by low mercury concentrations generally fall into two periods, one of stimulated immunological reactivity and the second in which it begins to decline.

In such a biphasic reaction, we often observed a series of other functional indicators. They are characterized by those shifts noted as a result of analyzing the dynamics of change of a second immunological indicator - agglutinin formation. Data indicates that, in test animals and also in the control group, both immunized, agglutinin titers rise. However, the dynamics of this rise have a diverse character. In the control group after each antigenic action, agglutinin titers rise regularly. In animals affected by mercury, the first vaccination as a rule, produces an even higher immunizing effect in comparison with that of the control animals. Subsequently second and especially at the third determinations there was an abrupt lag in agglutinin titers in comparison with the control group. This lag was more pronounced after revaccination at a time commonly distinguished by the high content of immune bodies in the blood. Thus, if in the first series, titers after revaccination of the controls were 1:6880, on the average, then in the test group it was about 1:524, that is, it was 13 times smaller (Figure 41). In the following series of

---

**Table 33**

Change in Percent of Active Neutrophils of the Blood Caused by Small Concentrations of Mercury (Average Values)

<table>
<thead>
<tr>
<th>Animal Group</th>
<th>Number of Animals</th>
<th>Days From Start of Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Experimental</td>
<td>18</td>
<td>38.54</td>
</tr>
<tr>
<td>Control</td>
<td>18</td>
<td>35.01</td>
</tr>
</tbody>
</table>

---

**Table 34**

Change in Number of Phagocytes in Experimental and Control Animals (Average Values)

<table>
<thead>
<tr>
<th>Animal Group</th>
<th>Number of Animals</th>
<th>Days From Start of Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Experimental</td>
<td>18</td>
<td>0.76</td>
</tr>
<tr>
<td>Control</td>
<td>18</td>
<td>0.81</td>
</tr>
</tbody>
</table>
Experiments at a shorter exposure, the agglutinin titer after revaccination in the controls was 1:7400 and in the test group, 1:876. The drop off in agglutinin titers in the test animals as compared to the controls becomes more evident if one takes the quantity of titers after the first vaccination by 100 (Figure 42). There is a definite lowering of response, the degree of which depends on the duration of the toxic effect: changes were most pronounced in animals in the 8 - 13th month of the experiment and less in those animals at the 3 - 5th month.

Data characterizing the dynamics of complementary activity of blood serum in experimental and control animals is presented in Table 35.
The table shows that there is usually an insignificant variation in complement titers in the control animals. Simultaneously in rats subjected to low mercury concentrations, there was a gradual diminution in the complementary activity of the blood. Later determinations revealed a further diminution reaching an average of 0.276 by the end of the experiments. Thus the complement activity of the blood in test rats was 1.5 times lower than initially.

Table 36 shows an even sharper decrease (1.7 times) in experiments with rats.

### Table 35

<table>
<thead>
<tr>
<th>Group of animals</th>
<th>Number of animals</th>
<th>Days from start of experiment</th>
<th>15</th>
<th>30</th>
<th>44</th>
<th>56</th>
<th>81</th>
<th>95</th>
<th>125</th>
<th>156</th>
<th>178</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>11</td>
<td>0.114</td>
<td>0.118</td>
<td>0.122</td>
<td>0.152</td>
<td>0.192</td>
<td>0.220</td>
<td>0.232</td>
<td>0.229</td>
<td>0.254</td>
<td>0.288</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
<td>0.108</td>
<td>0.112</td>
<td>0.102</td>
<td>0.016</td>
<td>0.130</td>
<td>0.140</td>
<td>0.126</td>
<td>0.136</td>
<td>0.116</td>
<td>0.128</td>
</tr>
</tbody>
</table>

As a rule, in these experiments, complement activity of the blood began to decrease after 2.5 - 3 months of mercury exposure and thereafter declined progressively. In the initial stage of the mercury effect some increase in complement activity was often observed.

There was no relationship between complement titers and immunization in either the experimental or the control group.

Study of the dynamics of change under these circumstances indicate that, low intensity irritation stimulates corresponding defenses temporarily, and then, during more prolonged exposure, the response diminished. Study of the preventive properties of the blood showed that it was possible to compare the protective properties of rabbit and rat serum (animals immunized on a background of prolonged low mercury concentration effects). When part of the mice who received 1 DIM typhoid fever culture combined with 1 ml immune serum, the control animals died only after the third (13.6 - 19%) - fourth (14.5 - 17%) days while over half (52 - 52.2%) survived. Mice receiving culture plus test animal serum, began to die even by the second (18 - 25%) - third (18 - 21.6%) day and only 22.5 (24%) of the animals survived.

Thus, blood serum derived from animals subjected to low mercury concentrations has lowered protective properties. This is shown not only by a higher percentage of mice killed, but in different lethality dynamics. Only one of the sera from test animals "protected" mice from challenge by typhoid fever cultures.

These effects reverse themselves slowly: 30 days after the end of mercury exposure, phagocytic activity of the blood was higher than at the end of the experiment, however in a majority of cases, it lagged behind the initial level.
The body requires a long time to recover from the specific effects of mercury of the functional (reactive) groups of cell enzymes and causing disorganization of a series of processes and functions affecting the status of response.

Mercury affects the chemical structure of the protein molecule and lowers its specific properties.

V. A. Belitser, 1954 and A. G. Pasynskiy, et al, 1955 have shown that the activity of specific proteins depends directly on the presence on their surfaces of special reactive centers made up of a combination of amino acids or their individual groups. Disorganization of these centers by mercury can lower the specific activity of enzyme systems, hormones and antibodies. Shifts in protein metabolism characterized by lowered synthesis processes with a predominance of structural changes undoubtedly reflect the general resistance of the organism to unpleasant external actions and appear, frequently, with a lowered immunological reactivity. One can postulate that a suitable situation can arise in the body and under the effect of other thiol poisons in the action mechanism of which shifts in protein metabolism block tissue SH– groups, appearing in the first plan and is a basic factor in the pathogenesis of occurring disorders.

Thus prolonged action of low mercury concentrations on mammals leads to changes in a number of immunological indicators: agglutinin titer, active leucocyte percent, phagocytic number, complement activity of blood serum. The dynamics arising under the influence of toxic effects of immunological shifts is characterized by two periods: an initial short-term stimulation of immunological response, and by its subsequent stronger suppression. There is a significant decrease in the preventive properties of the blood obtained from immunized animals subjected to chronic action of mercury.

Materials of I. Ya. Uchitel' and A. S. Konikova (1957) indicate that the sharp increase in specific antibodies under revaccination is accompanied by activation of synthesis of non-specific proteins by the serum. There is a definite correlation between antibody formation capacity, that is, the intensity of synthesis of specific and non-specific proteins, especially blood proteins. Our experiments on protein resynthesis in animals affected by mercury suggest that in micromercurialism, there is a suppression of this resynthesis and a decreased capability of the organism to form antibodies under antigenic stimulation and that these two are closely connected.

Immunity indicators, especially agglutinin formation, change under prolonged exposure to low mercury concentrations and reflect general physiological relationships.

Our data confirm opinions that changes in immunological indicators as a rule appear significantly earlier than many other signs of latent toxic effects even in the very earliest stages of toxic "aggression". These data correspond with that of V. K. Navrotskiy (19bo) that indicators of artificial immunological reactivity "... are especially sensitive during the action of the organism of environmental factors of very small parameterst".

<table>
<thead>
<tr>
<th>Group of animals</th>
<th>Number of animals</th>
<th>Days From Start of Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic data</td>
<td>15</td>
</tr>
<tr>
<td>Experimental</td>
<td>24</td>
<td>0.125</td>
</tr>
<tr>
<td>Control</td>
<td>22</td>
<td>0.135</td>
</tr>
</tbody>
</table>

*Data obtained after the first vaccination  
**After the second vaccination  
***After the third vaccination  
****After the fourth vaccination
CHAPTER XIII
MORPHOLOGICAL CHANGES IN ORGANS AND TISSUES AFFECTED BY MERCURY

Results of long-term experiments suggest that low mercury concentrations affect the mammalian system, producing primarily functional shifts: biochemical, hormonal, immunobiological, detectable, as a rule, only by very accurate methods. These shifts occur under favorable conditions in the absence of any marked symptoms of intoxication. Syndromes appearing during the development of experimental micromercurialism are characterized by certain general features, innate organismal responses to suitable toxic "aggression". In connection with this, a series of questions appear. To what degree are non-specific reactions and shifts, arising on a background of the effects of low mercury concentrations, connected with specific reaction mechanisms of mercury with SH-groups of cellular enzymes? Do "general" (monotypic) reactions arising in response to low mercury concentrations appear simultaneously with corresponding morphological changes? If the answer to the first question has been given to some extent in the preceding chapters, then the problem of morphological changes has been treated only partially.

It should be emphasized that morphological changes, observed in the organs and tissues of test animals, as a rule, appear on a background of decreased SH-groups, in connection with which, it is necessary to view the indicated changes from the position of their interaction with specific mercury action mechanisms.

It is necessary to note also, that in a majority of cases of low aerial mercury concentration (on the order of thousandths and hundredths of a mg/in3) specific micromercurialism phenomena did not appear (These phenomena appear only when the active concentration is in tenths of a mg/m3 and higher, and also in separate experiments involving the administration of mercury dichloride. What concerns investigations of organomercury derivatives in all cases of morphological changes described below are that symptoms indicate progressive intoxication (agitation, a state of marked depression, dynamia, progressive weight loss, increased reflex excitability, disruption of motor coordination, tremors, paresis, and then paralysis of the extremities, onset of seizures, at first clonic and then tonic).

Comparison of morphological changes in organs and tissues of animals poisoned by low mercury concentration, with disorders arising in response to more toxic organo-mercury derivatives, significantly ease analysis of these observed results. Our previous investigations showed that organic mercury derivatives, in comparison with metallic mercury vapor, have more pronounced cumulative tendencies (I. M. Trakhtenberg, 1950). There is also interest in comparing the degree and character of changes arising under the influence of mercury, and also in the dependence upon mercury buildup in the respective organs.

An additional question: Is there a dependence of the degree and character of morphological changes on mercury's route of entry into the body and in which organs and tissues does it accumulate primarily? Finally, in the process of morphological investigation undertaken in various animals (white mice, white rats, guinea pigs), we wished to determine whether the degree and character of the observed changes in the organs depended on the various species sensitivity of animals to mercury.

Along with pathomorphological investigations, we made gross study of the internal organs of test and control animals. The weight of the organs was expressed in terms of relative quantities -miligrams, relation to total body weight in grams.

Our data confirms that the body weight of animals exposed to the prolonged action of mercury vapor is higher than in the control group. In the first series we studied the liver and then the kidneys and lungs. There was an insignificant increase in the organ weight/ body weight coefficient of brain tissue, heart and endocrine glands.
White mice showed the earliest and most notable symptoms of toxic effect and morphological changes of the organs also appeared earlier and were more developed.

Rabbits were less sensitive to the effects of mercury and, in them, indicative morphological changes appeared only toward the end of the experiment and to a much lower degree. In white rats, symptoms of poisoning such as adynamia and weight loss had not appeared by the 4th - 6th month of exposure although a majority had marked changes in organs and tissues.

In autopsied animals killed during mercury vapor inhalation experiments, (mercury, ethylmercuric chloride, and ethylmercuric phosphate) the control and test groups displayed little difference in brain changes. Microscopic investigation of the cerebral cortex and medulla showed vascular destruction and dystrophic changes of the neurons in subcortical centers. Vessels were enlarged, full of erythrocytes. In individual animals there was hemolysis, stasis and thrombosis. Endothelial cells of fine vessels were swollen with partial desquamation. The perivascular spaces were enlarged and were filled with a pale red homogeneous liquid; sometimes there was pen-cellular edema. In a series of cases, there were focal, weakly developed dystrophic changes in the nerve cells of the cerebral cortex, partial or full chromatolysis, swelling of cells, nuclear displacement. Individual cortical cells were found in a state of chromatolysis and karyocytolysis. (Figure 43) Vessels of the brain, especially capillaries, were enlarged with significant perivascular edema: parietal thrombus, endothelial desquamation and proliferation of cell groups were observed.

In brains of animals killed as a consequence of chronic mercury vapor effects often there were observed hemodynamic disorders connected with focal dystrophic processes in nerve cells (especially with ethylmercury compounds).

In some animals, changes resembling a type of non-febrile encephalitis (swelling, nuclear ectopia, chromatolysis) was observed. After the longest exposure (more than 10 - 11 months) some cases showed irreversible (karyocytolysis, karyolysis) processes in brain cells (Figure 14i).

Protein granular dystrophy typified heart muscle changes sometimes accompanied by necrobiosis of the muscle fibers. These changes are shown in Figure 45. Note the dystrophic changes of the capillary endothelium (swelling and desquamation).

Prolonged exposure of the lungs to mercury produces vascular disturbance (congestive phenomena), increasing vascular permeability leading to focal hemorrhages and the development of pulmonary edema (Figure 14.6). More rarely there are changes in whole body resistance in animals subjected to mercury, and a lowered resistance of lung tissue as a result of tissue destruction after prolonged congestion (swelling and fatty dystrophy - Figure 47).

In the kidneys (Figure 148) vascular dystrophy, more rarely, necrotic changes arose after prolonged mercury exposure.

The spleen (Figure 49) differed little between the experimental and control groups (There was insignificant hyperplasia of follicular and interfollicular tissue, sometimes hemosiderosis. These changes reflect disruption of blood circulation and weakly developed hyperplastic processes (Figure 49).

Argyrophilic fibers of the stroma and vascular walls of all organs after impregnation with silver nitrate were swollen in lungs of poisoned animals, after 10 or more months, there were noted intra..alveolar development of argyrophilic fibers and the beginning of their collagenization (Figure 50).

Gross examination of organs during autopsy showed that endocrine glands in test animals did not differ from controls even after prolonged exposure, while the weight of the adrenals was higher. Changes in the thyroid gland were statistically insignificant. Sometimes there was adrenal swelling and small hemorrhages in the cortical layer.
Analysis of thyroid gland morphological changes was made after: 2 weeks, 1, 3, 3.5, 10, 11, and 12 months from the start of the experiment in those rats which had taken up radioactive iodine in the thyroid. General functional indices were also determined such as: follicular dimensions, height of epithelium and also the amount of interfollicular tissue. In evaluation of follicular dimensions, we used the following gradations: follicles up to 60 μ were considered fine, from 60 - 100 μ - average, and 7100 μ - enlarged. In both the test and control animals the structure of the gland was mixed. In one and the same organ different follicles were encountered. In most of the test animals final and average sized follicles with high cubical epithelium predominated. Highly prismatic epithelium was not seen even in animals with highly developed hyperthyroidism.

In control animals, the type of gland structure was similar with some colloid content and multiple resorbtive vacuoles. The stroma of the gland had a type of fine fiber. Table 37 summarizes data on animals killed at varying times after the start of the experiment.

From the table it is evident that rats killed during the first two months had follicles principally of fine and average sizes (55%).

Figure 51 shows morphological shifts in the interfollicular epithelium by the end of the second month.

After 3 - 4. months there was 51% fine and 41% average follicles, weakly staining colloids and the absence of certain colloids.

By the middle of the 4th month there were about 50% fine follicles.

After 5.5 months average and enlarged (60 - 200 μ) follicles predominated (74%), along with morphological changes indicating some decreased functional activity of the gland.
By the 10 - 12 month structural changes in the gland indicated recovery of its functional activity.

Consequently, in test animals low mercury vapor concentrations produce detectable structural changes, usually accompanying an initial rise in functional activity sometimes appearing by the second week and presaging glandular dysfunction. A tendency toward lowered glandular activity appears, and then after 2 months it increases.

This evidence of a phasic response of the thyroid to toxic irritation is confirmed in the works of Ye. I. Spyna (1954) on the non-specific character of certain endocrine glands to low intensity toxic action; Ye. I. Makovskaya (1967), Ye. P. Krasnyuk, S. G. Serebryanaya and Y (I. Makovskaya (1962) on the linkage of functional endocrine disorders with morphological changes stimulated by toxic substances.

Figure 52 shows some results of examination of adrenals, hypophysis and ovaries in poisoned animals. These organs showed various degrees of dystrophy, rarely focal, destructive and necrobiotic changes accompanied by vascular disorders. There was marked adrenal hyperemia, and highly focal dystrophic changes arose after 10 or more months of mercury exposure.

After 11 months exposure, rat tests showed fine dystrophic changes in the seminal epithelium and the intercanal stroma was rich with collagenic fibers and fibrillar cells (Figure 53).

This data agrees with the results of I. V. Sanotskiy, et al, 1967, which indicates that in manuals exposed to mercury, destruction of spermatogenesis and the functional state of the spermatozooids occurs, and there were also gonadotropic effects in females, illustrating the genetic effect of mercury in small doses. These small doses affect not only tissues, the nucleic acids of the generative cells, and also spermatozoid activity and, therefore, fertility. V. I. Vashakidze (1968) obtained analogous results in challenging animals with ethylmercuric chloride (Harmful effects of mercury on embryos, fetuses and the
outcome of pregnancy have been shown by G. A. Goncharyk (1968) and N. D. Mukhtarona (1965).

Harmful changes in the reproductive cells and organs have often been detected by clinical observations.

The preceding examples illustrate that not only high mercury concentrations, those exceeding the maximum permissible limits of 0.01 mg/in3 with 8 - 10 times can affect internal secretions through prolonged action. As a rule these low intensity changes are not highly developed and are reversible (Destructive changes are usually absent).

Morphological changes are also highly variable and depend, to a great extent, on individual and species sensitivity to the toxic effects of mercury.

Currently the significance of the initial reactivity of the organism in the course and development of pathological processes and their morphological equivalents is indubitable.

We have already shown that mercury as a trace element is present in nearly all biological objects usually in a majority of human organs and tissues. Mercury and its derivatives are strongly cumulative and organs and tissues accumulate supernormal quantities after prolonged exposure to it. We noted (1950) that marked destructive changes occur in depot organs, i.e., lungs, kidneys, liver, spleen, heart, brain, and under the effects of organosmercury vapors, lungs, brain, kidneys, liver and heart (A list was made of the presence of mercury in organs - from the highest content to the lowest) (Figures 511. and 55).

Indicatively, in all cases mercury was found in the thyroid and adrenal glands also. Another mercury distribution dynamics by organ was shown by us in comparing data obtained from exposing animals to mercury dichloride, ethylmercuric phosphate and ethylmercuric chloride via the digestive tract. In the first case, the greatest quantity of mercury was observed in the kidneys, then - in the liver, spleen, brain, heart and lungs (Figure 56). In the second case the order was: kidneys, brain, liver, spleen, endocrine glands, lungs, heart (Figure 57).
During the action of mercury compounds as vapors, high mercury concentrations were observed in the lungs. G. F. Ivanov (1936) found that in the lungs there is a feedback between blood and lymph circulation. Mercury and ethylmercury compounds, entering via the respiratory tract into the blood and lymph circulation, circulate there and, penetrating blood and lymph vessels of the lung, deposit in lung tissue.

S. I. Ashbel' and Y. A. Tret'yakova (1957) also detected high (0.27 mg/bOg fresh tissue; total 0.05 mg) mercury content in the lungs of a patient, dead of
mercury poisoning. The prolonged presence of mercury in all other organs indicates that mercury and its compounds from the pulmonary "depot" enter the systemic circulation, and deposit in other organs. Other authors have reported on the presence of mercury in the thyroid and adrenal glands, the hypophysis and the ovaries (S. I. Ashbel' and V. A. Tret'yakova, 1958; O. G. Arkhipova, 1961; M. F. Mirochnik, 19311.; A. Stock, 19140, et al).

Kh. Z. Lyubetskiy, 1958; Kh. Z. Lyubetskiy and D. V. Shrayber, 1959; V. A. Shalimov, 1956; F. Loretti, 1930; S. N. Crowson, J. B. King, 1957, have all reported on the dependence between the amount of active concentration inducing morphological changes and the degree of functional disturbance observed at still higher mercury concentrations.

First of all, the data indicate that even very low mercury concentrations in organs and tissues produce pathological changes of different intensity. On the whole these changes are reversible and only in special cases is there irreversible destruction. The latter is definitely connected with individual sensitivity, the duration of total exposure and the respective mercury concentration in the organs and tissues. Pathomorphological changes develop first in and are most damaging to the depot organs.

As a rule, low mercury concentrations are associated with dystrophic changes in the neurons of the brain (primarily in the cortex) and also a thickening and thinning of the basic argyrophilic substance. Under the later influence of mercury dystrophic changes appear (granular, vacuole, fatty), seldom necrobiotic, in the liver, kidneys, myocardium, thyroid and adrenal glands.

By the end of the experiment morphological changes in the internal organs were more highly developed and hemodynamic and dystrophic disorders were accompanied by necrosis and neurotic disturbance.

Low mercury concentrations often produce these changes without visible evidence of micromercurialism - on a background of apparent health. This agrees with the data of Ye. I. Makovskaya, S. G. Serebryanaya, Ye. A. Antonovich (1962).
Prolonged exposure to mercury inhibits protein resynthesis, depresses the reactive capacity of protein molecules, inactivates free SB- groups of cell proteins. Naturally, these disruptions of protein metabolism must be reflected in morphological changes. Dystrophic changes in organs and tissues are a consequence of metabolic disturbance.

Observations of organs and tissues of animals subjected to the prolonged action of low mercury concentrations, hemodynamic disruption and vascular changes, evidently, are caused by trophic destruction and lead to the development of hypoxia.

On the basis of the preceding studies and comparison of our results with literature data, it becomes evident that the dynamics of pathological changes arising during micromercurialism play as crucial a role as CNS and consequent vascular disorders with the appearance of hypoxia, thus the effect of mercury on the cardiovascular system, especially, on vascular permeability applies to all organs and tissues. Apparently, both indicated mechanisms are closely linked and mutually affect one another in the course of forming in the organism, affected by mercury, of corresponding morphological disorders.
Figure 54

MERURY CONTENT IN GUINEA PIGS POISONED BY MERCURY VAPOR (average quantities in mg/100g of organ)

```
<table>
<thead>
<tr>
<th></th>
<th>2.0 mg/m³</th>
<th>2.5 mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIDNEYS</td>
<td>112</td>
<td>97</td>
</tr>
<tr>
<td>LUNGS</td>
<td>625</td>
<td>71</td>
</tr>
<tr>
<td>LIVER</td>
<td>142</td>
<td>21</td>
</tr>
<tr>
<td>SPLEEN</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>HEART</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>BONE MARROW</td>
<td>08</td>
<td>13</td>
</tr>
<tr>
<td>THYROID GLAND</td>
<td>025</td>
<td>025</td>
</tr>
<tr>
<td>ADRENALS</td>
<td>007</td>
<td>015</td>
</tr>
</tbody>
</table>
```

Figure 55

MERURY CONTENT IN GUINEA PIG ORGANS UPON INTOXICATION BY ETHYL-MERCURIC COMPOUNDS

```
<table>
<thead>
<tr>
<th>Ethylmercuric chloride, 1.6 mg/m³, 31 day exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>At an average concentration of 3 mg/m³, 21 day exposure</td>
</tr>
<tr>
<td>2 mg/m³, 32 day exposure</td>
</tr>
<tr>
<td>2.5 mg/m³, 21 day exposure</td>
</tr>
</tbody>
</table>
```

```
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LUNGS</td>
<td>407</td>
<td>28.0</td>
</tr>
<tr>
<td>BONE MARROW</td>
<td>21.9</td>
<td>18.2</td>
</tr>
<tr>
<td>KIDNEYS</td>
<td>29.0</td>
<td>14.1</td>
</tr>
<tr>
<td>LIVER</td>
<td>20.1</td>
<td>10.9</td>
</tr>
<tr>
<td>HEART</td>
<td>9.8</td>
<td>8.2</td>
</tr>
<tr>
<td>SPLEEN</td>
<td>8.7</td>
<td>0.7</td>
</tr>
<tr>
<td>THYROID GLAND</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>ADRENALS</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>
```
Figure 56

MERCURY CONTENT IN ORGANS OF RABBITS 1, 2 AND 3
UPON MULTIPLE ADMINISTRATION OF MERCURY DICHLORIDE

(average amounts in mg/100g weight of organ)

Figure 57

MERCURY CONTENT IN ORGANS OF RABBITS 1, 2, 3 UPON MULTIPLE
ADMINISTRATION OF ETHYL MERCURY COMPOUNDS
PROPHYLAXIS OF CHRONIC MERCURY POISONING

"Don't continue to forget that scientific hygiene in the strength of internal content and as a natural science must necessarily encounter questions of practical living and cannot exclude anything applying to the preservation of society's health." (F. Erisman, 1883, Bases and tasks of modern Hygiene. Russian Thought 1883, 1, 38 – 49.

CHAPTER XIV

BASIC PRINCIPLES OF PREVENTING EFFECTS OF MERCURY ON THE ORGANISM

The prophylaxis of mercury vapor poisoning continues to be a major concern of public health agencies. Mercury and its compounds are known to be in daily large scale use and constitute a danger of intoxication, especially under conditions in which, previously, hygienists have never encountered it.

Below are recommendations based on many years of experiments by the Department of Industrial Hygiene, Kiev Medical Institute and on results of prolonged hygienic and technical investigations of other scientific and applied facilities.

Special hygienic investigations, experimental prevention of micromercurialism, and practical supervision where mercury and its compounds and mercury instruments are used, have determined basic principles for the prophylaxis of mercury poisoning:

-- Prevent the penetration of mercury vapor into the air of the work zone;

-- Protect structural elements of buildings, industrial equipment, and operating furniture from the possibility of mercury contamination;

-- Differentiated approach to evaluation of results of studying the mercury content of the environment, and correspondingly, to the development of health improvements not only under industrial but non-industrial conditions. In connection with the latter, it must be stressed that the adoption of 0.01 mg/m³ as the maximum permissible mercury content cannot be a criterion for the hygienic evaluation of the state of the external air at such facilities as academic (physics and chemistry classrooms of general and technical preparatory schools), medical (clinics, hospitals, dental offices, physical therapy rooms), and laboratories of higher educational institutions, etc.).

The prophylaxis of mercury vapor intoxication belongs to a complex of measures, the most important of which is the exclusion of mercury and its compounds in all cases where there is a possibility of their replacement by a harmless or less toxic compound.

This is a radical measure and must be used both in industry and the laboratory.

It is known that mercury is no longer used in the felt and mirror industries. Substitutes can be found in many more cases. Thus, mercury-filled differential manometers, widely used in a variety of industrial applications, especially at electric power stations, can be replaced by the membrane type, which are less dangerous.

The substitution of membrane types for float manometers we feel will bring some price increases in the whole complex of control and measuring devices at electric stations. This recommendation is made in the belief that it will have a number of positive effects. This replacement will obviate the necessity for mercury rooms costing about 4 - 5 thousand rubles. The economics of personnel cuts will be up to 8 - 12,000 rubles over 5 years. Money formerly spent on ventilators and the power to run them, special clothing and demercurizing measures will be saved. A position worked out with employees of the Kiev Branch of the All-Union Planning Institute "Teploelektroproyekt" shows the expense
involved in replacing mercury devices would be insignificant (about 4%) of the total complement of all control and measuring devices at such sites.

Mercury rectifiers at transport substations in Kiev have been replaced successfully by the flint type made by Zaporozhe and Tallin plants. Mercury vapor pumps used in creating vacuums in a variety of industrial and non-industrial uses, should be replaced by oil vapor or other non-mercury types if a high vacuum is not required.

In place of fragile, easily broken MacLeod mercury manometers, one can use ionization or resistance manometers.

Mercury contacts can be successfully replaced by Wood's alloy. In place of calomel reference electrodes, silver can be used instead.

In mercury V manometers of the DP-430 type, carbon tetrachloride, zinc bromide or tetrabromoethane can be substituted for mercury.

The specific gravity of these substances permits their use in place of mercury for the measurement of relatively small pressures.

One of the registering (GEM type) manometers can be used successfully in place of piezometers with mercury-filled V-tubes.

Mercury switches can be replaced by electrical ones, mercury in gas volumeters can be replaced by water.

Manufacture and repair of luminophores can be done without mercury, glass tubes with luminescent coatings should be filled with neon, rather than argon.

Rubber rings in certain machine building shops can be substituted for mercury rings in instruments.

For determination of percent compositions of combustible gases (methane, hydrogen) in gas mixture of shaft air of mines, refineries, oil wells, etc. mercury filled gas analyzers are in widespread use. They can be replaced by non-mercury containing types such as the VT 1 - 2 or the portable "Kievpribor". The Kuzbass Central Scientific Research Laboratory of Mine Safety has developed such a gas analyzer. This volume-optical gas analyzer OOG-1, has been used for the determination in shaft air samples of methane, carbon monoxide and oxygen, by a gas exchange method, (methane optically) using a special (type LI-4) interferometer. The OOG-1 and the VG Sch-2 are completely mercuryless and results in improved hygienic conditions for gas analysis laboratory workers, and also removes all danger of explosion in methane analysis. The device is in wide use in mine safety laboratories of some of the Kuzbass mines for systematic sampling. Use of the VG Sch type is easily converted to volume-optical. LI-k interferometers can also be used in hydrogen determination.

In hospitals contamination can affect not only the health of laboratory personnel but that of patients.

Here there is a concrete possibility for the radical prophylaxis of micromercurialism. Thus, thermocouples can replace mercury clinical thermometers. A transistorized thermometer was developed in the Laboratory of Mine Automation and Telemechanics of the Siberian Department, AS USSR. The original is an electrical medical thermometer TEMP-60, used to measure temperature not only at various surface points but in soft tissues and cavities.

Abroad, a mercuryless thermometer wax filled, (heat expands the wax) has been developed. It is held under the tongue for 4 - 5 minutes and then inserted into a device which registers the heat.

In some developmental laboratories, thermometers have been constructed of unbreakable polymer instead of glass. These new materials conduct heat and polarize light well.
Water, with 5% HCL, can replace mercury in universal and similarly constructed (Holden type), gas analyzers.

Stephens devices, used in normal and topographical anatomy laboratories (mercury containing) pose a danger exacerbated by the normal presence of formaldehyde vapor in such places.

Artificial TN, generated at many medical facilities by the use of argon lamps containing mercury (types ARK and PRK) which are different from mercury-quartz lamps in that little mercury is added.

Mercury vapors must be prevented from harming dental office personnel.

In the preparation of silver and copper amalgams, the preparation room must be isolated by barrier walls coated with mercury-impermeable substances. Floors in these places must be covered with asbestos tiles, plastic, linoleum, vinyl or other plastic materials. The site must be equipped with forced ventilation (hood with mechanical activator). During amalgam work, the air speed through the system must be not less than 1.5 m/sec. It is best to use a hood like that of V. S. Karabanova and L. A. Derum (1961). The simplest suction device suitable for use in dental offices was recommended by I.L. Gerchikov (1962).

The daily amalgam supply and the mortar and pestle used in preparing it, should be kept in special cabinets under the ventilation hood. Mercury in use should be kept in enameled, ceramic or, best of all, plastic vessels covered by rubber corks and lids.

The most radical solution to the problem of mercury contamination prevention in dental offices is a change in the method of preparing fillings, which would completely exclude mercury vapor at the site. Therefore, a mechanical amalgam preparation method should be substituted for the mercury method and be done by hermetically sealed apparatus and instrumentation.

It is vital that there be wider use of silver amalgams in place of copper, for which is recommended an original apparatus designed by S. I. Kozlovskiy (1965). This apparatus prevents contamination of the site by mercury, simplifies the use and improves the quality of the filling.

In conducting a series of biochemical and other analyses, it is necessary to limit the use of both metallic mercury and mercuric chloride. For example, for the preparation of a developer in the current widely used electrophoresis method of studying protein fractions, less poisonous calomel should be used as a protein fixative.

Modifications in the laboratory amperometric titration instruments widely used in biochemical laboratories exist. Pre-eminent among these modifications is that of Kh. F. Shol'ts, 1964, which lowers the possibility of laboratory employees contacting mercury. Further perfection of a mercuryless device is the battery-fed one of I. G. Ishchuk, 1969.

Mercury dichloride can be eliminated from aluminum isopropylate production processes used in making streptomycin. For this, absolute isopropyl alcohol (99.5% pure) mixed with aluminum shavings and add to the reactor with carbon tetrachloride.

To realize the prevention of the mercurialism hazard, there must be a radical measure -- removal of mercury. Even this measure will not completely eliminate the mercury, but its content in industrial and other raw material and end products must be reduced as much as is feasible. The Kiev Chemical Fiber Combine improved conditions by reducing the mercury content of alkali used in inerculization of cellulose. Acting on our recommendation, the Ministry of the Soviet Chemical Industry set the mercury limits in electrolytic alkali as 0.0001% in 100% product in place of the earlier 0.00125% content allowed.

In circumstances in which mercury cannot be eliminated entirely, it is necessary to work out technical schemes, and also to construct laboratory and industrial
instruments and devices which exclude the possibility of aerial mercury contamination of the work site.

In making a variety of mercury filled instruments, unbreakable glass, or polymer and special synthetic filter materials should be used.

Vacuum devices should be protected by plastic polarized at room temperature and attached to the device.

**TABLE 38**

<table>
<thead>
<tr>
<th>Name of mercury proof coating</th>
<th>Resistance to alkali</th>
<th>Acid resistance</th>
<th>Mercury desorption capability</th>
<th>Washability of mercury</th>
<th>Stability to chemical demercurizing compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete and cement solutions treated with thickeners as recommended by Tsniilkyinstryyo</td>
<td>+</td>
<td>-</td>
<td>Poor</td>
<td>Good</td>
<td>Resistant to ferric chloride, hydrogen sulfide, permanganate and dichloramine</td>
</tr>
<tr>
<td>Acid-resistant ceramic</td>
<td>+</td>
<td>+</td>
<td>Average</td>
<td>Satisfactory</td>
<td>Same as in p.1.</td>
</tr>
<tr>
<td>Asbestos ebonite laminate</td>
<td>Average and weak concentrations</td>
<td>+</td>
<td>Average</td>
<td>Poor</td>
<td>As in p.1.</td>
</tr>
<tr>
<td>Diabase laminate</td>
<td>+</td>
<td>+</td>
<td>Average</td>
<td>Poor</td>
<td>As in p.1.</td>
</tr>
<tr>
<td>Phenolite laminate</td>
<td>Weak concentration</td>
<td>+</td>
<td>Average</td>
<td>Good</td>
<td>As in p.1.</td>
</tr>
</tbody>
</table>

A special plexiglas cabinet is the best protection for mercury filled instruments. The whole instrument can be protected in the enclosure. Only the mercury stopcock, necessary for regulation, is outside the cabinet. Devices should be constructed if possible of impact-resistant, inert parts with special attachments (cartridges with iodized charcoal, activated manganese dioxide, with silica gel iodo-copper sorbent) which bar mercury vapor from the workroom.

Under industrial conditions, processes and operations connected with the use of metallic mercury and its compounds should be isolated in their own one-story building.

It is very necessary to keep mercury and non-mercury operations strictly separated. Structural elements should be tightly built and sealed if necessary.

It is especially important to observe hygienic measures in the refining of cinnabar and metallic mercury, in smelting mercury from ores and in the amalgamation used for enriching non-ferrous metals. Applicable are the measures of N. I. Petrova (1965) and L.A. Ryzlik (1968). The latter noted measures in the amalgamation process at ore enrichment plants (especially gold) "should be complex, at the basis of which is the requirement provided work with exposed mercury".

One of the most important conditions of health improvement in the production environment is hermetization of feed. According to E. I. Vorontsova (1962) this measure alone can lower the mercury vapor content from 0.5 - 1 mg/m3 to traces.

In chemical plants producing mercury compounds, basic measures are hermetization and mechanization of processes, and effective ventilation of work sites. These measures ought to be especially strict in the synthesis of organomercuricals.
Laboratories employing relatively large amounts of mercury, or connected with heating it, and also laboratories where there are open mercury surfaces should be isolated in a glass enclosure with one sealed entrance and should have a minimum of one room where toxic substances are not taken. It should use closed mercury devices concentrated primarily at one special equipment site, which ought not to serve as a place for prolonged gathering of personnel.

Construction elements of the building should be of highly mercury-impermeable materials with the least adsorption capacity towards mercury vapor. The requirements call for wood floors to be covered with asbestos-ebonite tiles, linoleum, vinyl, polyvinyl chloride or phenolite - 2 tiles. Table 38 shows the basic properties of mercury-impermeable coverings.

Asbestos-ebonite tiles are not damaged by water, moderately strong alkalis or weak or moderate acids except nitric. These tiles are laid with hot asphalt glue.
or glue composed of one part by weight of BF-4 glue, 30-40 sec. viscosity, and 3 parts quartz meal.

The chemical stability of relin is almost the same as the above tiles. It is applied to cement with hot asphalt and hot rolled. Relin can also be attached by a vulcanization method.

Polyvinylchloride plastic is resistant to alkalis, weak and medium acids and water.

Vinyl plastic has good electric isolating and mechanical properties, absolute mercury impermeability and is one of the best materials for covering floors, laboratory benches, working surfaces or exhaust hoods, etc. It is resistant to alkali, acids of average concentrations, is less resistant to water, dissolves in relatively concentrated acid, especially by 40% nitric acid, oils, etc. Before installation vinyl is degreased, heated, and then glued to cement with hot asphalt or BF-14 adhesive and hot rolled. The layers are heated with a special heater or by a high frequency method.

Pehnolite-2 tiles are resistant to water and weak acids. They are attached with asphalt adhesive and seams are filled with arzamit glue or sulfur asphalt adhesive.

Resin linoleum, vinyl plastic and other plastic floor coverings should start 10 cm from the wall and be attached with moldings. Mercury impermeability of tiles increases if they are glued down with adhesives where are themselves mercury impermeable (asphalt, fluoroasphalt, etc.).

The most effective mercury impermeable adhesive is based on a modified asbovinyl, phenolformaldehyde, fural and epoxy resins, and asphalt-sulfur mixtures. Water and other pipes must be tightly made and sealed. For this a filled asphalt adhesive, vinylchloride paste, vinyl plastic or fluorinated mineral mass is used.

Mercury impermeability of concrete floors is achieved by a) initial treatment with 10% CaCl2 and then with 3% NaF in three cycles; b) treatment with sodium-hydrofluoric acid (fluorates).

In this way water resistant, strong and non-porous surfaces are achieved.

If the floor is covered with reinforced concrete tiles, their interseaming must be treated to retard cement expansion which might occur when floors are washed with water and they must be dry when treated with chemical solutions which impart mercury impermeability. Seams can be filled with arzamit-adhesive, containing a phenylformaldehyde resin, a powder form filler and setting accelerator. The adhesive should be prepared before each use and only in quantities which can be used in the next half hour. The adhesive is applied to a dry surface previously treated with a 5 - 10% Rd solution. For the next four days the hardening temperature must not fall below 20°C or the floor washed with water.

In sites where both agressive alkaline media and mercury are employed, floors should be made of specially formulated reinforced concrete incorporating liquid glass (specific gravity 1.05 g/cm3) and thrice treated with liquid glass and CaCl2 solutions.

Ceramic floor tiles should be used (in the case of aggressive acid media) which have been treated not less than five times with 10% CaCl2 3% NaF. Results of treatment are improved if each application is made under pressure for six hours. The tiles are laid on a reinforced concrete base. Before laying, the adhesive is heated to 160 - 180°C and applied no more than 4 mm thick on the concrete base. Sodium silicate solution provides an acid resistant layer. It has a specific gravity 1.36 - 1.38 g/cm3 and contains quartz pellets and fillers not exceeding 26%; its thickness should not exceed 15 mm. Seams are filled with a mixture of 50% sulfur, 32% mineral fillers, 15% asphalt and 3% naphthalene in which the asphalt is heated slowly to 160°C and the sulfur, etc. added.
Walls, furniture, instruments and equipment must also be protected from mercury contamination by coating dry surfaces, where possible, with a shellac or perchlorovinyl resin, quartz or diabase filled (25 - 35, 76 - 65 and 2 - 3%). After drying surfaces are painted with KhSE-1 or KhSE-3 paint with a final coat of perchlorovinyl resin.

**Figure 58**

**FILTER-INDICATOR DEVICE OF S.F. YAVOROVSKAYA**

Door sills, etc. and other wooden parts can be painted with a perchlorovinyl enamel plus 1 - 5 layers of shellac after preliminary coatings as described above.

Walls and other construction elements can also be "final" painted with nitro enamels as well.

Equipment at industrial sites where mercury is handled should be protected in large ventilated chambers, heated in winter, with exhausts.

Under production conditions, air flow through the exhaust system can contaminate other areas unless such systems are equipped with a modern filter such as that shown in Figure 55.

A maximum number of operations should be done under the exhaust hood. Air flow through all ventilation chambers used in industry and in the laboratory should be at least 0.5 m/sec generally and not less than 1.5 m/sec when heated mercury is present. Such a hood is shown in Figure 59. It should not be below the working surfaces of drawers and cabinets. The ventilator should be turned on 30 min. before work with mercury begins and turned off 30 min. after it ends. The air in the system should then be purified through suitable filters.

1. Carbon-aluminum filters-in which mercury vapor adsorbs onto activated charcoal and aluminum chips. The filter is easily regenerated by heating and simultaneous suction of the pure air.
2. Iodo-charcoal filter which results in the formation of mercury iodide.
3. Manganese dioxide filter containing free chlorine; yield mercury chloride.
4. Antigas filter with ordinary or improved charcoal with activated Rd.
5. Mark "G" antigas filter with activated charcoal adsorbent and free chlorine.
6. Copper-iodine filter with a silica-gel or other sorbent.
7. Liquid sorbent filter with two solutions in two vessels. In the first, nitric acid, which traps mercury, and in the second, and oxidizes the released nitric oxide. This type of filter is considered less suitable than those with solid adsorbents.

In order to exclude worker contact, all operations should be conducted with sealed apparatus or mechanized if possible.

Places where leakages are possible should be equipped with vacuum pumps.

All mercury-containing instruments should be placed on metal bases under exhaust hoods. To prevent glass part breakage, they should be kept away from doors and moving equipment parts.

Internal safety rules should stress safe habits and the need for personal hygiene.

All those working with mercury, its compounds or mercury-filled instruments, must wear special, protective clothing (hats, coveralls); work with open mercury should be done inside plastic glove boxes or under the hood; clothing must not touch the mercury. Taking special clothing home is absolutely forbidden. Special protective clothing must be made of dense white material which sorbs mercury poorly. Coveralls must be tightly stitched, have no pockets and must be cleaned at least once a week.
Cleaning proceeds as follows: Contaminated clothing or coveralls are freed of dust, loaded into a washing machine and rinsed for thirty minutes with cold water. The rinsed clothing is washed with washing soda-soap solution (1/kg clothing) and washed for thirty minutes at 70 - 80°C, treated with 1 - 25 HCl. Then it is washed in an alkaline solution for 20 minutes at 70 - 80°C, which frees the fabric of 96 - 99% of its mercury.

In cases of momentary massive mercury vapor penetration into the worker respiratory zone, for example, through accidents, mark "G" antimercury industrial antigas filters are used to remove significant quantities of mercury. In the absence of such equipment, F-46-K respirators with mark "G" cannisters containing silver oxide, activated manganese dioxide, or iodized charcoal as sorbents, can be used.

For absorption and removal of mercury under industrial conditions, a vacuum pump equipped to keep mercury from the ventilation system can be used if kept in the work area.

Mercury-contaminated technical solutions can be wiped from floors, equipunt stands, instruments and other surfaces. Mercury can be collected and washed using a device shown in Figure 60.

a) Small droplets can be collected using a paste described by Ye. A. Peregud (1947) containing pyrolucite (MnO2) and 5% HCl, 1:2 which is applied to the surface to be treated, left one-half hour, and then removed first with a spatula, then with a brush; the mercury droplets poured into a special vessel containing acidified water.

b) Amalgamation onto special sheets which are kept in a special closed vessel.

c) A vacuum cleaner adaptation attached to a water flask to prevent contamination of the pump and hose (Figure 60).

d) The so-called "mercury magnet", a copper spiral, treated with nitric acid and amalgamated. The adhering mercury droplets are washed of and stored under water in a closed resin vessel.

e) A special attachment "catcher" for collecting individual droplets of mercury (Figure 61).\n
Disposal of collected mercury into the sewage is not permitted.

After sorbtion the contaminated place must be washed with 0.2% potassium permanganate with 5 ml HCl/l (specific gravity 1.19) or with 20% water solution of ferric chloride.

It is always necessary to follow mechanical desorbtion of mercury droplets with chemical decontamination so that most of the mercury will be transformed to a non-volatile compound, a film of which will prevent mercury from evaporating.

The most important demercurization procedure is, therefore, the emulsion and complete conversion of mercury droplets to an insoluble compound.

One of the most effective solutions for this is 20% trivalent ferric chloride which changes mercury to a fine, black powdered compound ("black mercury") consisting of very fine mercury droplets covered with a thin film of monovalent mercurous oxide; after a few days a white film of divalent mercuric chloride appears, later changing to the orange divalent mercuric oxide.

Such a film, even in 3 - 14 mm drops maintains its stability for 2.5 months, after which it starts to crack. Monovalent mercury sulfide or chloride films obtained in demercurization of other substances are less stable and their protective powers weaker.

However ferric chloride must not be used for treating metal surfaces (except lead), which decompose from its action. Also it leaves on plaster, cement, or
unpainted wood surfaces a yellow stain. It is a good agent for other surfaces (tile, etc.). After using it hands and special clothing must be washed. Powdered sulfur is one of the solid demercurizers used in laboratories.

**Figure 60**

**DEVICE FOR COLLECTING MERCURY**

Keeping the temperature below 18°C will reduce mercury evaporation. It is necessary to prevent raising of the air temperature in mercury worksites, such as air conditioning, ventilation improvement, increasing thickness of building insulation, painting walls white for better reflection of the sun's rays, etc.

Building sanitation measures are significant in the demercurization process.

To facilitate removal of "mercury locations", independent of their use, walls should be smooth and level. Joints between them, floors, ceilings should be curved. Furniture should be on legs leaving a free distance of no less than 20 cm from floor level. Working surfaces of tables should prevent beeding and securely fixed. Tables and exhaust hoods should not be below the working surface of drawers and cabinets.

A basic need is regular equipment and site cleaning. In industry this thorough cleaning should be done once every ten days with washing soda solution.

Once each quarter chemical demercurization should be done, (0.2% acidified aqueous solution for potassium permanganate, 2% ferric chloride solution with subsequent water washing of the chemical residues from the floors).

In the laboratory cleaning should be done every day before an experiment and after its completion. It includes wet sweeping of floors and wiping of walls, tables and other furniture. Windows should be opened when cleaning is done (Twice a month, more thorough cleaning should be done (wash ceilings, walls, furniture, window sills, moldings, etc. with soapy water).

Cleaning materials used in "mercury locations" should be stored in closed cabinets marked with a red label.

Once each quarter, "mercury objects" should be demercurized chemically with a) a paste, recommended by Ye. A. Peregud (1917); b) 0.2% acidified (HCl) potassium permanganate solution (specific gravity 1.19, 5 ml acid/1 of solution); c) 20% ferric chloride solution (S. F. Yavorovskaya, 1949) prepared in the cold (eschew heating), 200g ferric chloride/800 ml water; d) gaseous or dissolved H2S; e) 4 - 5% solution of mon- or dichloramine in CCl4. Use with 14 - 5% polysulfite solution for surfaces; f) 5 - 20% ethylenediamintetra acetic acid and 95 - 80% hyposulfite; 25 g of this mixture/1 H2O.

Currently, the most widely distributed chemical demercurizing agents are ferric chloride and potassium permanganate.
The gaseous method has too many drawbacks, primarily keeping the H2S within the permitted limit of 10 mg/m³.

V. A. P'yankov (19148) showed that chlorine demercurization involves not only toxic danger but also corrosion of metal parts.

It is necessary to use chemical methods when mechanical cleaning is not successful enough and when there is a danger of adhered mercury becoming a secondary contamination source. The mercury bound chemical into sulfide or chloride coated droplets must be removed as the coatings are not very strong and will break down under abrasion, increased temperature, etc. and metallic mercury will again be released into the air.

Additionally, since these compounds are biologically active substances, great care must be taken in handling techniques and application conditions.

Polyvinylchloride and linoleum coverings can be cleaned with H₂O and ferric chloride solutions. Vinyl plastic resin linoleum, ceramic tiles, cement, or cement-stone compositions may be cleaned with these and also with KMnO₄, acidified with 5% HCl and dichloramine in CCl₄. Except for sodium polysulfide, the above compounds may be used on phenolite tiles.

Asbestos-ebonite tiles cannot be cleaned with chloramine in CCl₄. Only ferric chloride, sometimes H₂S solution, may be used for perchlorovinyl coatings.

In addition to chemical, thermic demercurization of contaminated structural elements has recently come into use (S. F. Yavorovskaya, 1965, 1968). The installation is heated to 200 - 250°C with the simultaneous pumping out of the contaminated air. Such a heating chamber is shown in Figure 62.

These measures undertaken for reasons discussed above, are also necessary to prevent secondary aerial and depot contamination of children's institutions and living quarters.

"Demercurization" as a term should mean conclusive mercury removal with the undertaking of special structural repairs including removal of contaminated elements and media used in demercurization (M. N. Korshun, 1968).

The amount of demercurization should be dictated by each case, arising from the degree of sorbtion contamination at the site itself and character of subsequent use of the site (Thus in place of communal use such as children's institutions, the aerial mercury level must be reduced to less than 0.0003 mg/m³.
Research data indicates that the effectiveness of such measures depends on the intensity of the sorbed mercury source and on the depth of mercury penetration into structural elements.

In the presence of third degree sources or massive contamination by second degree sources, the entire surface layer of the structure must be physically removed (i.e.: plaster walls and ceilings). Glazed wall tiles can be subjected to thermal demercurization. If there is then any residual contamination they should be washed with 5 - 7% flowers of sulfur or powdered sulfur. For later use of the site the air must be freed of mercury. Thus depots in structural elements must be eliminated and the site painted with mercury-impermeable paints, lacquers and enamels. The number of protective coatings required depends on the residual depot. Hundredths of mg/g require base coats, enamels and lacquering while thousandths of mg/g require only one coat of base and enamel.

Results indicate these methods are highly effective against even third degree contamination sources and appear to be economically feasible as well.

Before repainting or replastering a laboratory site, the surface should be demercurized and new plaster up to 0.5 cm applied.

When there is first degree contamination, mercury can be encapsulated by perchlorovinyl covering, nitroenamels or oil base paint. If subsequent mercury operations are not planned the surface layer of plaster can be removed and 2 - 3 coats of whitewash applied.

Where it is possible (from an architectural or structural point of view), thermal demercurization can be used independent of the secondary source intensity. In the presence of massive contamination, thermal methods can be used on wall plaster if subsequent mercury operations are planned and the plastic is then painted with a mercury-proof substance. If future mercury use at the site is not planned thermal demercurization should precede removal of the plaster.

B. S. Lavkov, 1966 in Bulgaria proposed applications of ceramic resin (if no further mercury use is intended) or oil base paint.

As a rule, floor coverings are mercury droplet sources and they must be removed for thorough demercurization to be effective, and a rubberized subflooring installed beneath the new floor.
For third degree contamination, all contact between sub-flooring and the air of the floor below must be removed.

When up to 0.002 mg Hg/g is present in wooden furniture, prolonged (2 - 3 months) "ventilation" of the furniture is recommended at high temperature (summer). At very high mercury concentrations, furniture should be destroyed by burning.

If contaminated furniture is to be reused in a mercury site it must be painted with mercury-proof paint before reuse.

Wood panels, window sills and frames must be freed of old paint by singing with flame from a burner before new coatings are applied.

Industrial hygiene must be maintained by systematic sanitary inspection.

To conduct this, it is necessary to find out the basic possible aerial mercury vapor contamination sources, establish hygienic requirements based on technological conditions, separate production processes and operations connected with mercury use, workers must be properly equipped, ventilation must be effective, and proper anti-mercury precautions must be applied to all furniture and fixtures. Continuous control over the presence and concentration of the aerial mercury vapor content must be maintained.

Qualitative analysis for the presence of mercury can be done simply with treated papers and is suitable for school and medical-biological use by all personnel. The papers can be prepared easily by immersion in 10% potassium iodide or 10% cuprous copper solution in a glass vessel, then filtering, washing and drying the precipitate according to standard methods. The dried papers can be stored in a glass vessel. In general the longer the time from initiation of paper exposure it begins to turn pink, the less mercury is present. See below.

<table>
<thead>
<tr>
<th>Number</th>
<th>Date</th>
<th>Work Site</th>
<th>Place</th>
<th>Name of</th>
<th>Results of indications</th>
<th>of the presence or absence of stained papers, exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Quantitative analysis for mercury in the air should be done in strict accordance with "technical conditions in a method of determining the mercury vapor content of the air" No 122 - 1/96 or 7/V 1958.

Sampling and determination equipment arrangement is shown in Figures 63 and 64. When mercury vapor is present in the air, the iodized silica gel takes on a pink color, the intensity of which is compared to a standard (colors produced by known concentrations).

It is also necessary to determine periodically the sorbed mercury content in production equipment, working furniture, clothing by a) reaction of mercury in an iodine in potassium iodide solution, or b) thermal desorption of mercury with subsequent condensation of its vapors (Figure 61.) for further colorimetric analysis. One must remember that the presence of paint in the sample complicates colorimetric analysis and makes the analysis by the sublimation method impossible.

Colorimetric analysis should be done by the N. O. Polezhayeva (1956) method described in "Instructions and methodology of organizing investigation of contaminated air" NO. 404-62 from 26/VI/1962. Determining sorbed mercury in samples is also based on mercury uptake by a solution of iodine in potassium iodide with subsequent colorimetry.

Currently, the most widely distributed automatic mercury analyzers at the IKRP-446 and IKRP-450, based on the absorption of 2537 A UV by mercury vapor (K. V. Deyanova, D. V. Isayev, O. D. Khalizova, 1961).
More recently an original atomic absorption device for rapid mercury vapor determination has come into use (N. I. Petrova, N. B. Shleykher, A. Z. Ryazanov, 1968). While the N. O. Polezhayev method requires 20 - 30 min. for analysis, this method requires only 3 - 5 seconds. Determination of mercury in the air of the work zone of the Nikitovsk Mercury Combine showed the device to be simple and easily used.

Medical-prophylactic surveillance of industrial workers possibly adversely affected by mercury vapor is done by medical departments of the enterprises themselves. It involves preventive, before beginning work, and periodic medical check-ups, once or twice a year depending on amount of mercury exposure (The goal of the survey is to maintain good health and to determine those in which the initial symptoms of mercury effects. It is especially important to determine these initial pathological effects of micromercurialism so that they can be medically reversed. Also, the presence of such persons signal that sanitary-hygienic improvement measures are needed.

A decree of the Ministry of Health USSR (No. 136-M, 7 September 1957) required medical supervision of persons in "mercury professions" including therapeutic, neuropathological, dental, psychiatric and gynecological examination. Laboratory analyses recommended are: hemoglobin content, ESR, leucocyte content, urinary mercury and urobilin, general urinalysis, erythrocyte and reticulocyte count. The first five of these are obligatory. In doubtful cases there is diagnostic use of unithiol perorally (5g twice a day) until analysis is made.

Medical contraindications to embarking upon work with mercury and its compounds include: epilepsy, obvious neurosis (neurasthenia, hysteria, psychasthenia) and also neurotic states of different etiology, organic CNS disease, psychic distress, evident endocrine-vegetative disease, chronic or recidivist gingivitis, stomatitis, alveolar pyorrhea, chronic colitis, obvious liver disease, nephrosis, nephritis, nephrosclerosis, ulcers, optic nerve disease, glaucoma and active tuberculosis. These diseases are severely aggravated by mercury intoxication and leads more rapidly to more severe micromercurialism.

Periodic medical examinations should include persons who have only intermittent, or who have long ceased to have, contact with mercury. Temporary absence from work with mercury is required when the initial symptoms of micromercurialism appear. Such persons can be treated as outpatients and given unithiol (0.5g twice a day for three days with a three-day interval),
diathermy of the liver and kidney region, Shcherbaks' galvanic collar and vitamin therapy with subsequent improvement in a sanitarium if needed.

Upon the development of a functional stage of more pronounced chronic mercury effect (mercurialism) the temporary removal from all contact with mercury, and hospitalization of the patient in a special occupational pathology ward, a full course of therapy (antidotes, physical therapy and vitamin therapy) and rest under sanitarium conditions is required.

When the organic stage is reached (onset of tremors) the patient must be completely removed from all contact with mercury and hospitalized far from any mercury source for recovery.

Permanent cessation of all contact with mercury is indicated for those persons who upon contact with mercury, have developed the above described diseases and pathological states which would be medically contraindicated for initiating work with mercury.

An important place in medical service is the therapeutic-prophylactic diet of person likely to be exposed to mercury vapor. Rules for such preventive therapeutic diets are found in a decree of the State Committee of the Council of Ministers USSR and of the Presidium V Ts SPS from 10/11/1961, No. 122/3.

At high risk industrial facilities, such diets should include large quantities of lecithin and complete protein with added thiamine and vitamin C.

The Institute of Nutrition AMS USSR, has worked out a six-day menu of hot breakfasts, according to recommended guidelines, norms for using products to prepare such breakfasts, reminders for workers receiving food, and also pointed out the necessity of including lipotropic substances in the diet which exert a beneficial influence on the state of the liver and CNS - lecithin and others as noted above. Currently, experimental data points out the importance of using pectin substances, which increase mercury build-up in the system. (O. G. Arkhipova, 1961, 1966). It is known that carboxyl groups of galacturonic acid, anhydrides of which form the basic structure of pectins, can unite with metal ions. Pectins occur in many food products of plant origin, composing from 0,5 - 39% of them. There is much pectin in fruit juices, berries and tubers.

CHAPTER XV

HEALTH MEASURES FOR THE PREVENTION OF MERCURIALISM UNDER LABORATORY CONDITIONS

In speaking of the potential danger of micromercurialism under laboratory conditions, of the possible sources and escape routes of mercury into the air, one should note a series of circumstances pertaining to it.
During use of a series of instruments (polarographa, Langmuir pumps, manometers, etc.) in amalgamation and other processes, the application of chemically pure mercury is required. Yet mercury purification is an inherent part of the work of such a laboratory since mercury is removed from glass stop cocks which often come unseated and result in the spillage of mercury onto the floor and bench surfaces. The drying in porcelain dishes of purified mercury over an open flame after its washing in distilled water, plus improper manipulation, from a hygienic viewpoint, leads to the intensive release of mercury vapor into the air. Above we have discussed the various mercury filled instruments present in such laboratories.

Additionally, in some laboratories we surveyed mercury is used as tare or ballast. Easily breakable glass instrument parts abound in laboratories and lead to mercury contamination of the sites. Laboratory air contamination is usually connected with the use of and mechanical destruction of technical thermometers, as a result of recording abrupt temperature fluctuations in substances being investigated. Other sources are a large group of instruments such as vacuometers, discharge meters, traction meters, etc.

We recommend for the sanitation of such facilities, radical hygienic measures, primarily maximum replacement of all mercury filled instruments. Current storage of mercury in glass containers with plastic or cork stoppers does not prevent the vaporization of mercury into the air. Even in laboratories where mercury is stored in glass vessels with ground glass stoppers, mercury has been found in thousandths to hundredths of a mg/m³ in the absence of any other mercury source, because the glass stoppers have not been greased with vacuum grease, an extremely necessary measure.

Earlier surveys indicated that mercury vapor can penetrate a layer of water and other liquid media. This is explained by the thermo-dynamic law that above two non-reacting, immiscible liquids, the total vapor pressure is the sum of the two individual vapor pressures. To determine the speed of penetration of mercury vapor through a liquid layer, special 3 cm diameter glass cylinders designed by P. P. Pugachevich (1961) were used. Distilled water, tap water, vaseline and machine oil, benzene, 5% HCl and then a few ml of pure mercury are placed in a cylinder. The cylinder is closed by a ground glass stopper, greased with vaseline. Mercury vapor which penetrates the liquid layer accumulates under the stopper, from where aspirated air samples are taken for mercury determination.

Tests showed that in three days mercury easily penetrated a one meter layer of tap water, and through the same layer of benzene and vaseline, leaving 0.0002 mg/Hg in the investigated volume and above the water layer, 0.0009 mg in 20 cm. In a repeated experiment the figures were 0.0001 mg and 0.0005 mg respectively. After three days 0.0003 mg Hg had penetrated a 1 meter mineral oil layer, there was 0.0004 mg above the benzene layer and less than 0.0001 mg above the machine oil layer.

According to P. P. Rygachevich (1961) the best protective action is exerted by 5% HCl. Our experiments showed that it is second to machine oil (after 3 days there was 0.0002 mg Hg in the 20 cm air space).

This data is applicable not only to research laboratories, but also to places where mercury is used in amalgamation such as dental offices, etc.

Large quantities of mercury (15 - 20 Kg or more) should be stored in special cabinets in steel drums with steel screw stoppers. Vessels and attachments for safe mercury transport should be available. In the laboratory 30 - 40 ml Hg should be stored in the exhaust hood in special metal or earthenware flasks. The same quantity in sealed ampoules, should be stored as shown in Figure 65 in ordinary laboratory cabinets.

Larger quantities must be stored under conditions excluding aerial contamination by vapor. Glass vessels with greased ground glass stoppers should be stored in metal containers under the exhaust hood. Larger quantities should be heat dried only under vacuum.
Each operation involved in heating mercury should be done in bottomless heaters to minimize spillage and mercury contact with the hot surface.

Apparatus used for purifying mercury must be constructed without resin outlets or other parts that can contaminate the already purified mercury.

This walled tubing must not be used for work with mercury, since breakage is closely connected with the danger of contamination, against which no preventive measures are completely effective. Even thicker tubing may break if mercury is poured into it too quickly. Therefore, in such pouring it is necessary to use flasks with tapered ends. For massive work use smooth surfaced treated columns.

We take up the problem of prophylaxis of micromercurialism in the laboratory and problems relating to the danger of mercury contamination in academic buildings, especially, secondary schools.

Earlier it has been emphasized that despite the fact that metallic mercury and mercury filled instruments are used in demonstrations, physics and chemistry courses in secondary schools, problems of hygiene and labor protection in academic mercury use have not been dealt with. Separate recommendations will be discussed below as they have been insufficiently discussed in standard handbooks and manuals.

Thus in "Demonstration experiments in Physics in the VI and VII classes of the secondary school" edited by A. A. Pokrovskiy (1956) in the section on "Requirements for class demonstrations" a series of requirements for demonstration, there is no need stressed for safety, especially with mercury experiments. The same prevails in "Physics instruction methods for the eighth year of school" and other handbooks.

We recommend that mercury safety procedures be included in future editions of textbooks and methodological handbooks.

For effective prophylaxis of mercury contamination in classrooms of schools and technical colleges, academic space and apparatus, must be so constructed for maximum limitation of mercury filled instruments. This must be linked with preventive regulation of academic laboratory instruments and apparatus.

The most radical preventive method to bar the harmful effects of mercury is to exclude it completely from the academic environment and replace it in instruments with harmless or less toxic compounds, make demonstrations involving mercury and its compounds as brief as possible. Mercuryless instruments have been described in "Physics in the schools" but are insufficiently used in practice. Of the mercuryless instruments successfully used, is a device for demonstrations on the theme of "basic properties of gases", devices,
demonstration vapor properties, saturation of air and determination of atmospheric pressure. Strong polymers can be substituted for glass parts of "mercury apparatus".

More mercury than that needed for the current year' a demonstrations should not be stored in classrooms.

Teachers must prevent mercury air and structural material contamination in classroom equipment and furniture, and maintain personal hygiene in mercury handling.

To a definite degree these measures have already been realized in physics and chemistry classrooms corresponding to the structural norms set forth in SN: P II - Lh - 62. Floors are constructed with reagent resistant floors. Walls should not permit the accumulation of mercury.

Responsibility for maintainance of hygienic requirements lies with a series of health and inspection agencies. Hygienic requirements for demonstrations are for complete safety for participants and teachers.

Tables and floors and working surfaces must be treated with mercury impermeable substances not only to prevent secondary sorbed mercury depots but to facilitate demercurization and mechanical cleaning operations.

Physics and chemical classrooms should be equipped with exhaust hoods and all mercury manipulations (filtration, purification, filling instruments, etc.) should be done under it. Its ventilation should begin 30 minutes before the beginning of mercury work, and should have an air speed through it of 0.5 -- 1 m/sec.

Laboratory personnel must observe hygienic rules for work with mercury. With this goal in mind we have worked out a sanitary program for those working with mercury in physics and chemistry classrooms. As a result of the program approved in 1965 by the Chief sanitary epidemiological board of the Ministry of Health, USSR, workers must receive full instruction in the toxicological characteristics of mercury, to take instruction in proper procedures for demonstrations and experiments with mercury, be familiar with the principles of qualitative and quantitative air analysis for mercury, must master the techniques of these analyses and know how to prepare and use chemical demercurizing solutions.

Physics and chemistry teachers or instructors must wear white coveralls and shoes when doing mercury demonstrations. Manipulations with open mercury must be done in a glove box under the hood. Students should not handle mercury in completing their laboratory work.

Systematic control must be exerted over the coveralls, shoes and equipment. Qualitative analysis for the presence of mercury can be done with treated papers, which can be prepared by participants under the guidance of the teacher. Results can be recorded in a special journal according to the following format:

| No. | Date | Name of work site | Results indicating the presence or absence of reaction of treated papers; exposure time | Place for gluing on of used treated paper with the indicator papers glued on. |

To prevent possible secondary mercury vapor sources and the contamination of adjacent sites, it is necessary to locate these classrooms in first floor rooms facing N.E. Floors, walls, benches, ceilings, etc. must be covered with mercury-proof coatings as used in the entire site.

Strict control of metallic mercury and mercury-filled instruments, especially those considered "normal" for school use (up to 0.5Kg) must be maintained.
Certain other measures to prevent mercury intoxication in the schools have been set forth in the publication of the Chief Sanitary-epidemiological board of the Soviet Ministry of Health, "Instruction and methodological rules for the construction, equipment and maintenance of physics and chemistry classrooms where mercury and mercury-filled instruments are used" (No. 510-64., 1961).

Currently there are other official documents regulating the use of mercury in the schools. Among them "Instruction and methodological rules for work with mercury in physics and chemistry laboratories in intermediate and secondary schools", published by the Ministry of Health and the Ministry of Education RSFSR, a decree of the Ministry of Education, (Latvian) SSR "Safety measures for mercury use in schools of the republic" (1961). The Latvian Ministry of Education prohibits the use of metallic mercury in demonstration experiments in intermediate schools and in classes 1 - 8 of secondary schools.

IN PLACE OF A CONCLUSION

"...unavoidable point of departure in all hygienic investigations is the tendency to go to those laws which govern the health of man all the general and specific phenomena, an understanding of which indirectly or directly elucidate these laws..."

(F. Erisman, 1882; F.F. Erisman, Collected publications, V. I., Medgiz, 1959,

We reflect again on the words of F. F. Erisman with which this book began and compare them with those above.

The effect of human occupational and productive activity on the state of health has definite modern significance on the further development of industrial hygiene as one "of the most prominent aspects of hygiene".

In light of the ideas stressed at the beginning of the book, from the contemporary point of view the mercurialism problem reflects a series of principal positions to hygiene of more than general interest.

Based on the data above, we come to the following conclusions.

Earlier it was considered the harmful influence of occupational and industrial factors, in this case, a variety of chemical substances, lie at the bottom of most occupational diseases. With respect to occupational pathology as a rule, the most conclusively and relatively simple aspect can be to establish a link between degeneration and working conditions, specifically human industrial activity. Recently, more and more facts have built up indicating the level and structure of "non-occupational" diseases is caused by daily contact with chemical environmental factors. Also it should be emphasized that in the past the level of chemical poisoning detected has been high, while recently it has decreased with the recent sharp decrease in toxic concentrations at work sites.

In connection with this, the task of studying toxic effects on workers under modern conditions should include not only analysis of the effects of agents having pronounced effects, but of irritants which have a detectable effect at very low levels. Under suitable conditions, there occur a series of latent changes, especially biochemical, neurohumoral, and immunobiological in nature. These changes do not cause gross somatic disturbance, rather they are reflected in delicate reflex and metabolic shifts. Truly, they arise first of all as a result of the effect of toxic substances on interoceptors, especially tissue, having a high sensitivity to tissue metabolic changes, Chemical substances, as low intensity irritants should be used to study shifts at different stages of the metabolic process. The use of radioactive isotopes can detect synthetic changes in the absence of morphologic signs of destruction. In connection with this we agree with S.V. Anichkov (1958) who said that biochemical shifts precede morphological changes, as a consequence of which the synthesis of tissue proteins can be used as the indicator of the toxic effects of low concentrations of chemical substances.

In analysis of proteinemic shifts developing in micromercurialism, we have already cited the research of V. A. Belitser (1951.) and
A.G. Pasynskiy (1952) which links the activity of specific proteins with the presence on their molecular surfaces of specific reactive centers made up of united amino acids or their separate groups. Evidently, toxic substances, which block reactive groups of protein molecules and change their chemical structures, disorganize these centers and can lower the specific reactivity of enzyme systems, immune bodies, hormones, etc. Shifts in specific protein activity in connection with a depression in synthetic processes and the predominance of destructive changes, cannot, naturally, but be reflected in the total reactivity of the organism challenged by various harmful actions.

Small mercury concentrations under chronic experimental conditions produce changes in the status of immunobiological reactivity. Shifts can be detected in agglutinins, complementary activity of the blood serum, phagocytic activity of peripheral blood neutrophils, and preventive properties of sera. Toxic effects aggravate microbial pathology in animals.

In mammals subjected to prolonged toxic effects, antibodies do not protect the organism from infection. This is based on data indicating that small mercury concentrations predispose the organism to influenza (1964). Prolonged exposure of mammals (white mice) to low mercury concentrations (0.008 - 0.02 mg/m³) leads to a significant increase in the susceptibility of mice to pathological influenza virus strains. This is shown by a decrease in the LD₅₀ and a more severe course of infection. In the experimental group more mice died (86 - 90.3%), than in the unexposed animals (60.2 - 68%), additionally the experimental group died more quickly. The significant difference was in the appearance and degree of pneumonia in the affected animals. The hemagglutination reaction of influenza virus was recorded more often in the lungs of animals subjected to toxic effects.

One must agree with the point of view of O.G. Alekseyeva (1964) the '... the extreme lability of immunological reactions requires care in the treatment of the results obtained." Actually, such immunological indicators, for example, as the phagocytic reaction of blood neutrophils can change under the influence of external agents, the effect on the organism of which is not indicated by any unpleasant consequences. It is necessary in the use of this indicator to pay attention to the quality of the criterion of harmfulness in only a marked decrease in phagocytosis (A. F. Stoyanovskiy and. T.V. Rasskazova, 1961), to evaluate the indicated reaction by not only one, but by several indicators (phagocytic index, % phagocytes, etc.). Additionally it is vital to assess the character and degree of changes in other indicators connected with immunity reactions, which apply to the mechanism of the changes arising. Prolonged exposure to small mercury concentrations leads to a depression in tissue protein resynthesis. These phenomena are closely interconnected.

In humans remember that the prolonged effects of low concentrations of toxic substances depend on individual susceptibility.

A given irritant produces its respective reaction only at a definite threshold level. At this level it produces a specific response depending upon the functional features of the reacting systems, and also depending on basic physiological properties of the latter. The action of an irritant at subthreshold strength, as a rule, does not produce the specific response. However, there are simultaneous corresponding changes in the activity of various organs and tissue, which, although not specific, lead to the appearance of functional and metabolic shifts, reactivity changes, excitability, lability, "readiness" for subsequent stress.

Such non-specific affects produced by low concentrations of chemical substances (enzyme poisons) include those of thiol poisons which affect enzymes having general functional groups.

Thiol poisons, especially mercury and its compounds, reacting with SH- groups of proteins, lead to the lowered activity of various enzymes, containing sulphydril groups. This produces a series of disruptions in the functional activity of many organs and tissues of the organism. These disruptions are heterogeneous and
diverse in character. In persons long exposed to low mercury concentrations there are a series of monotypic functional shifts. The latter are manifested in subjective complaints, breakdown, increased fatigue, headaches, etc., and also objectively recorded, although not sharply developed. vegetative neurosis, reversible functional shifts in higher nervous activity, less muscular capacity. Analogous changes can be noted under the effects of other toxic substances. N. S. Pravdin (1934.) spoke of "the chemical depression of work function", the depression of physiological function the destruction of which even under conditions, if pathological shifts are still absent, can lead to decreased labor productivity.

Prolonged exposure to low mercury concentrations, affect the higher regions of the CNS relatively early. In this the observed damage does not differ from analogous CNS changes produced by a variety of other chemicals and these may be related to a non-specific toxic effect. On the other hand, the appearance of CNS changes must have at their base a specific genesis. Thus, for example, in mercury experiments this is confirmed by the fact of the dependence of conditioned reflex activity on tissue SH- groups.

As mammal experiments show, especially, that if simultaneously with mercury preparations containing free SH- groups are given, reflex and differentiation are not destroyed. The administration of the indicated preparations on a background of an already developed pathological process can restore disrupted conditioned reflexes.

Even such a universal CNS reaction of the organism to toxic action can lie in specific mechanisms of so-called primary biochemical reactions.

In light of the surveyed position, morphological studies are of interest, a result of which a series of general regularities in the reaction of the nervous system was in response to the action of occupational poisons varying in action mechanism (M. S. Tolgskaya, 1954., 1959).

Changes produced have a reversible character: after one or two months after cessation of toxic action.

The results of these morphological studies indicating early response of the cortex and non-specific character appearing through the action of low concentrations of various toxic substances correspond with clinical observations during the study of the initial stages of intoxication (E. A. Drogichina, 1957). Thus in the development of the initial stages of chronic mercury, lead, CS2, etc. poisoning occurs in two phases. In the first of these, functional shifts are characterized by a state of heightened excitability of the cerebral cortex, that, evidently, is connected with weakened inhibitory processes and in the first place processes of internal inhibition; the second phase, is accompanied lowered cortical excitability, and certain inertness of cortical processes.

The above discussed CNS shifts produce, initially, emotional instability, increased analyzor excitability, lability of vegetative reactions, and then an asthenic syndrome, a state of irritable weakness. These non-specific (general) CNS phenomena of various occupational poisons often precede further developing shifts and disorders, which in the developed stage of intoxication, takes on "its 'specific aspect."

From the point of view of the interaction of primary biochemical reactions and non-specific functional shifts, the appearance of which are linked to these reactions, special interest can be shown in experimental analysis of the cardiotoxic activity of mercury, completing the presentation of the above data of relatively specific genesis of the disruption of higher nervous activity in experimental mercurialism.

Changes in cardiac activity can arise not only through toxic effects but under the influence of other harmful factors, in that they in their appearance have to a significant degree, a monotypic character, such that the heart responds to initiation only by the presence of changes in contactility, conduction and rhythm. However, at the basis of activity changes of a given organ, like the
heart, lies fully determined biochemical mechanisms. Various irritants can affect specific steps in biochemical processes which cause corresponding functional activity changes in the organism.

Our EKG data indicates that mercury-caused changes appear to be non-specific, however, experimental administration of dithiol indicates the specific genesis of the recorded disorders. This data agrees with that of Kh. S. Koshtoyants (1961), the SH- group inactivation caused by other thiol poisons, especially cadmium chloride, also produce EKG changes, negated by the effect of cysteines which then return to normal levels.

On the one hand, the primary action mechanism of toxic substances on these or other enzyme processes are connected on the other hand with functional changes specific for the given organ. At the same time a "specific" (in a given case for heart function) mechanism can undergo, as described above, under the effect of the most diverse damaging factors, that give basis to the researcher in like cases to speak of the "non-specific" character of the recorded shifts. Evidently, that similar demarcation is extremely conditional. This is accomplished by a similarity and a contrast of specific and non-specific changes on the molecular level, having a place at both the cellular and system levels. The interconnection of specific and non-specific, especially that related to multiple mechanisms, which in the end lead to a monotypical functional effect.

In looking at certain principal aspects of experimental analysis of a toxic effect, it is impossible not to note that the character of the reaction of the organism to these actions depend on the strengthened duration of the chemical irritant, and oft the functional state of the reacting substrate.

On the basis of the action of low mercury concentrations, we can be convinced that in the dynamic of functional shifts and destruction appears general (sufficiently universal) character of the reaction of the organism to low intensity toxic effects. At the time, when under the influence of pronounced toxic actions already relatively rapidly developed depression of function, low intensity chemical irritants determine another character of response reaction; at first a certain stimulation of corresponding effect, and then, according to the increased length of the effect -- its depression.

Strict attention must be paid to lability and the diapason of "physiological variation" in the dynamics of this indicator, the degree of its "normal" lability. In this there cannot be a monotypic approach to the evaluation of the observed shifts, such as in some cases, even wider variations of the indicators studied fit into the "physiological norm," in others -- a very insignificant already signifies the development of the pathological process. In connection with this especially important is the establishment of concrete quantitative amounts, characterizing the limits of "physiological variation."

Knowledge of the "quantitative criteria" for the interpretation of the character of the changes arisen become extremely important not only during hygienic evaluation of external factors in the process of their experimental study, but also in the subsequent undertaking of production surveys as in the following example.

To judge the state of hemopoeisis under various toxic stresses, in our experiments the widely used bone marrow neutrophil and erythroblast maturity index and also the nuclear shift index in the peripheral blood. When the nuclear shift index of peripheral blood neutrophils becomes higher than 0.2, the bone marrow neutrophil maturity index exceeds the 1.2 - 2.1 limit, and the erythroblast maturity index falls below 0.35 - 0.7, that such variation can be considered as exceeding the physiological limits.

According to data of M.M. Gimadeyev (1963), obtained in conjunction with our work, which has been described above, the decrease in SH- group content, caused by low mercury levels precede conditioned reflex activity changes, in which an SH- group drop to 12 - 21.6° does not produce any damage. Conditioned reflex activity shifts are observed only when (toward the end of the second month) the SH- group content has reached about 56% of the initial level. Even in the known
variability of the quantities, sufficient shifts in cell protein SH-groups can be regarded as a toxic effect indicator of thiol poisons including mercury.

There is still one more subject to deal with.

In experimental modelling of toxic action, the difference in age sensitivity on a background of sharply delineated shifts and destruction can be averaged. Simultaneously, differences produced by these low intensity effects are very important. Thus, evaluation in the course of our investigations of the character and reaction features of the hypophyseal-adrenal cortical system in toxic actions, we could be satisfied that the functional activity of this system under such effects rose to a definite level. The recorded shifts were unevenly distributed among various age groups. Thus, in old animals, the functional activity of the adrenal cortex under the prolonged influence of mercury rose later and was less well expressed than in young animals.

These and other data confirm the existence of important age differences in the development of the general adaptation syndrome in response to external action, that, truly, depends on the differences in aspects of neurohumoral regulation at various ages. (V. V. Frol'kis, 1967).

Thus, we tried to generalize certain data obtained in mercurialism studies to show the regularities of low intensity toxic action.

And now we come to one of the most important aspects of this problem -- the hygienic mercury content normalization in the air of the work zone.

We note that in recent years, sometimes there is a tendency toward the following formulation of the problem. What can be considered the "principal direction" in modern hygienic research -- the hygienic normalization or "the study and development health improvement measures, that is, methods designed to remove the unpleasant effect of one or more factors" (Ua. Kh. Neyshtadt, 196h).

In connection with this, F. G. Krotkov argued the necessity of further broadening of experimental studies, particularly in industrial hygiene, stressing that such studies "...are absolutely necessary for hygienic normalization of industrial poisons and the development of labor protection regulations..."

For maximum realization of the first item under so-called "natural conditions" it is necessary to realize that all the varied factors of the industrial environment which underly hygienic improvements, can be divided into two groups: factors which daily affect humans and their physiological adaptive mechanisms (microclimate), and factors, with which man encounters exclusively or primarily in production circumstances and in relation to which he "... does not have well developed adaptive mechanisms." (A. L. Letavet, 1962).

In relation to the first group, one must determine the optima. (in a series of cases the minimum or maximum) hygienic standards for the microclimate, nutritional norms, proper housing, physical and intellectual loads, etc., and in this decision, based on research into desirable physiological conditions for the organism, also in evaluation of the second group of factors, basis significance lies in the determination of their permissible limits under industrial conditions (dust, vibration, ionizing radiation, etc.) Toxic factors belong to this group (G. Kh. Shakhbazyan, I. M. Trakhtenberg, 1965).

The permissible aerial toxic content to a significant degree depends on the character and sensitivity of selected indicators. Evidently, permissible content recommendations will differ depending on whether they are based on observations of visible damage or on research into fine reflex reactions. Of interest is the position of N. V. Lazarev (1967) about the exclusive importance of "... discovering the relationship between elementary 'breakdown' and adaptive reactions during prolonged low intensity toxic irritation of the organisms.

It is known that the intake of poison does not produce a toxic effect in all cases. It occurs only when the organism's adaptive regulatory mechanisms are
inadequate to eliminate the harmful agent. A.I. Cherkes (1939) found that during the prolonged, repeated action of small doses of poison, the latent period can be prolonged, so that in the course of which, there are no observable pathological changes in the organism characteristic of that poison. This period, according to Cherkes, is distinguished by gradual reorganization "... of the organism under the influence of foreign chemical irritants from physiology toward pathology in this can be called pre-pathological poisoning.

For the hygienist and toxicologist the answer to the question of the shift from a protective physiological reaction to a pathological state is not only of theoretical interest but has an evident applied use.

On the one hand, it is necessary "always to consider how much environmental factors tax this protective function, without risk of exceeding that limit, beyond which is the pathological process." (G.V. Pol'bort, 1950), and on the other, the stress limits of this function should be taken in cognizance of the quality of one of the basic criteria for solving hygienic standardization problems.

Maximum allowable quantities must not exceed those levels of established normative indicators since organisms have a broad adaptive range, the level of which may be inadequate "if the external toxic level or other stresses were to rise suddenly" (A. A. Letavet, 1962). In a series of industrial sites chlorine often is present along with mercury (electrolysis shops). There is also lead, formaldehyde, nitric oxide and isopropyl alcohol, etc. V. G. Lappo (1960) and S. A. Fridyland (1965) found that summation of toxic effect occurred when low concentrations of mercury and lead or cyanide were given to animals.

Mercury as a low intensity environmental factor is one of those agents under which "...adaptation to the environment often is purchased at the cost of significant morphological and functional shifts." (I. V. Davydovskiy, 1962). Thus evidence applicable to this has been obtained by B. A. Anchugin (1966), and his five years observations of normalization of mercury damage to the redox processes shows that it attains the status of compensatory mechanisms and have a temporary character.

It is important to remember that even by 1930, when the first sanitation laws regulating the limits of permissible concentrations for twelve widely distributed toxic substances, mercury was last on the list, and only trace amounts in the air were permitted. Indicatively, in the first project, even the maximum permissible aerial mercury concentration was not allowed in the work zone. In that not only the "specific production conditions" but also "the concentrations, which in time can produce chronic poisoning (tents and hundredths of a mg)"; were considered. N. D. Rozenbaum (1933) related mercury to the number of industrial poisons, the aerial content of which, even as traces were completely forbidden. In 1939 limits were set in accordance with general sanitary norms (osr-13214.-B) as 0.01 mg/m3.

It becomes evident that many of the earlier established hygienic normals should be revised in the light of modern conditions and experimental evidence.

A survey of foreign sources shows that the permissible mercury level in the Soviet Union is much lower than abroad (7.5 - 10 lower than that of the USA, England, West Germany and other countries). These foreign investigators have suggested that the maximum permissible concentration be 0.1 mg/m3 at which "only 10% of poisoning cases suffer from some form of heavy damage". Others considering latent forms have set the limit at 0.02 mg/m3. However there is a well known case of a university laboratory where the aerial mercury content was 0.1 mg/m3, and its personnel had symptoms of chronic mercury effects (L. Yoldwater, M. Kleinfeld, A. Berger, 1956).

There was a later foreign report stating that setting the limit at 0.1 mg/m3 was no guarantee against the development of chronic intoxication.

Thus, in various mammal species (white mice, white rats, guinea pigs, rabbits, cats) subjected for a year or more to mercury concentrations equal to or close to 0.01 mg/m3 developed shifts in a series of biochemical processes, in the endocrine system, immunobiological reactivity, blood, and cardiovascular system. These shifts developed on a background of pathological changes involving reactions with thiol groups, and inactivation of the reversibility of changes during different biological processes.

It was also established that in persons, having prolonged contact with mercury there is a tendency to develop moderate hypochromic anemia, changes in functional activity of the olfactory analyzer, increased uptake of radioactive iodine into the thyroid gland, lower muscular capacity, diminished working ability and other shifts at mercury concentrations exceeding 0.01 mg/m3 2-3 times. We feel that at these higher concentrations, a relatively large number of cases (36.5+-2.49) develop an asthenovegetative syndrome of toxic etiology. That fact shows that earlier established limits do not incorporate a sufficient "reserve coefficient".

Thus, on the basis of experimental studies discussed above (I. M. Trakhtenberg, 1958, 1961, 196k) the maximum permissible mercury concentration should be lowered as argued in previous works.

The main conclusion arising out of the preparation of this work is that there is a need for a maximum increase in hygienic requirements for labor conditions of mercury workers.

The introduction into practice of effective sanitation and health improvement measures, the combination of the latter with a series of organizational measures, especially the withdrawal of mercury and limitation of its use is endorsed by a wide circle of practicing physicians, hygienists and clinicians -- from the modern aspect of the problem of the chronic action of mercury on the organism. Such a complex of problems, the successful solution of which will secure the effective prophylaxis of mercurialism.

BIBLIOGRAPHY

K - Kiev L - Leningrad M - Moscow


Alekseyevskiy, Ye. V. Microchemical methods for mercury determination and the problem of the mercury hazard. L., 1931.

Alekseyevskiy, Ye. V. Journal of General Chemistry, 1933, 3, 360.

Alekseyevskiy, Ye. V. Activated manganese dioxide. L., Khirnteoret, 1937.


Ashbel', S. I. Tret'yakova, V. A. Pharmacology and Toxicology, 1958, 2, 78.


Belitser, V. A. Progress in Modern biology, 1950, 1, 53.


Berger, L. I. Works of the 3rd All-Union odontological meeting, 12 June 1928, M., 393.

Bogatyreva, V. P. Improving working conditions for handling mercury. M., 1939.

Braver - Churnobul'skaya, B. S., Belonozhko, G. A. Unithiol in therapy of heavy metal poisoning. In: Thiol compounds in medicine. K., 1959, 139.


Vvedenskly, N. Ye. Excitation, inhibition and narcosis SPb., 1901

Veger, A. M. Industrial pathology and Hygiene, 1930, 11, 57.


Veger, A. M. Rydneva, Ye. P. Ibid.


Vigdorchik, N. A. Industrial Hygiene, 1928, 1, 23.


Gabelova, N. A. In: Treatise on the use of radioactive isotopes in medicine. M., 1953, 139.

Gabuniya, G. Sh. Industrial Hygiene and occupational diseases, 1961, 8, 50.


Galoyan, Sh. A. In: Thiol compounds in medicine. K., 1959,


Gelf'man, I. G., Derviz, G. K. Industrial hygiene and safety technology, 1936, 6, 13.

Gel'fand, A. M. Labor improvement and a revolution in living conditions, XIX, M., 1925, 6.

Gel'fand, A. M., Smirnov, A. P. Hygiene, safety and labor pathology, 1929, 5, 22.


Gimadeyev, M. M. Hygiene and Sanitation, 1959, 8, 73. Ginsburg, S. L. Hygiene and Sanitation, 19148, 8, 24.


Gol'dinan, B. I. Hygiene and Sanitation, 1956, 6, 33.


Gol'dshteyn, B. I. Effect of sulfhydryl groups on the biological properties of tissue proteins, K., 1955.


Gorokhod, L. L. Collection of scientific and applied works of the Ukrainian industrial sanitation inspection, K., 1941, 157.

Goroshevskaya, T. V. In: Works of the plenary scientific conference of the Novosibirsk Medical Institute 195 - 1957, Novosibirsk, 19, 70.

Goryacheva, L. A. In: Industrial toxicology and clinical aspects of occupational diseases of chemical etiology. M., 1962,


Gofman, M. Z. Hygiene and Sanitation, 1963, 12, 73.


Gupalo, Yu. V., Besch, M. G. Hygiene and Sanitation, 1958, 12, 79.


Drogichina, E. A. Industrial hygiene and occupational pathology, 1957, 4, 34.


Dunayevskiy, M. N., Pey sakovich, I. M. Occupational hygiene and pathology, 2, M - L, 49.

Yegorov, V. P. In: Microelements in agriculture and medicine. Subjects of reports of the fifth all-union meeting. Ulan-Ude, 1966

Yegorov, V. P. In: Microelements in the biosphere and their use in agriculture, and medicine in Siberia and the Far East, Ulan-Ude, 1967


Zil'ber, A. A. XVI session of the general meeting of the AMS USSR. Subjects of scientific papers. M., 1962, 23.


Ivanov - Smolenskiy, A. G. In: Works of the Ukrainian institute of industrial hygiene and occupational diseases. XX, Khar'kov, 1939.


Izrael'son, B. I. H iene and Sanitation, 1960, 2, 3.

Ishchuk, I. G. Laboratory Affairs, 1969, 3, 181.

Kazakevich, M. A. Early changes in the nervous system during chronic industrial mercurialism. Author's abstract cand. diss. M., 1914.5.

Kazakevich, M. A. Industrial hygiene and occupational diseases, 1960, 6.

Kazakevich, D. V. Hygiene and Sanitation, 1950, 11, 53.

Kalash'yan, A. Early diagnosis of chronic micromercurialism, Author's abstract cand. diss. Sverdlovsk, 1940.


Klimova, L. K. In: Thiol compounds in medicine. K., 1959.


Koyranskiy, B. B. In: Works of the Second All-Union Meeting on Industrial Hygiene and Safety Technology. 1930, 204.


Kostygov, N. M. Pharmacology and Toxicology, 1958, 3, 64.

Kostygov, N. M. Effect of thiol compounds (mercaptojantaric acid and unithiol) on the effects produced by mercury compounds, Author's abstract of cand. diss. L., 1959.


Korshun, M. N. In: Hygiene and Toxicology, K., 1967, 16.

Korshun, M. N. Hygienic significance of secondary contamination by mercury of the air of industrial and laboratory premises to the problem of mercurialism prophylaxis. Author. Cand. diss. K., 19


Kozitskiy, G. I. Laboratory affairs, 1960, 1, 53.


Krivoglaz, B. A. Industrial hygiene and occupational diseases, 1963, 8, 15.


Krotkov, F. G. Hygiene and sanitation, 1969, 6, 3-7.

Krupitskaya, I.D., Pisarevskiy, I.L. Hygiene and sanitation, 1965, 1, 71.


Kuznetsov, A. Mercury. MBE, 1, 1934, 29, 378.


Kulik, G. I. Physician's affairs, 1959, 10, 1065.


Kurinniy, I. L. Subjects of Reports of the All-Union Conference on Sanitary Protection of the Air. K., 1959, 52.


Lazarev, N. V. Industrial hygiene and occupational diseases, 1957, 6, 27.


Lappo, V. G. Hygiene and Sanitation, 1960, 12, 11.

Lappo, V. G. Toxicology of simple cyanides in their individual and combined action with mercury salts. Author's abstract cand. diss. M., 1962.

Latmanizova, L. V., Lashchenko, N. S. Chronaxy and tonus of the skeletal muscles. In: Materials on the problem of industrial hygiene and clinical aspects of occupational diseases. VII. Gor'kiy, 1957, 73.

Lebedev, V. A. Mercury poisoning in industry and means of combatting it according to materials from Kievan sites. Author's abstract cand. diss. K., 1914.5.

Levitskiy, V. A. Problem of the physical state of the population of the Podolsk district. M., 1901.


Levitskiy, V. A. Industrial hygiene and safety technology, 1935, 2, 81.


Litins'kiy, O. S. People's medicine, 19240, 6, 70.

Lyubetskiy, Kh. Z. Characteristics of certain liver functions under the influence of mercury. Author's abstract cand. diss. Tashkent, 1953.

Lyubetskiy, Kh. Z. Characteristics of certain kidney and liver functions under the influence of mercury. Author's abstract cand. diss. Tashkent, 1953.

Lyubetskiym Jg. Z. Problems of hygiene and sanitation in Uzbekistan. Tashkent, 1958, 50.

Lyubetskiy, Kh. Z. In: Scientific session of the Sanitation Institute held in Cherchik. Tashkent, 1953, 214.

Lyubetskiy, Kh. Z. In: Problems of hygiene and sanitation of the USSR. Subjects of scientific works. Tashkent, 1950, 43.


L'vov, A. N. Collected works of the All-Union Scientific Research Institute of communal sanitation and hygiene, III, 1939, 178.


Lysenko, Ye. I. Mayevskaya, V. P., Naumova, I. S. Hygiene and sanitation, 1956, 9, 91.


Marchenko, Ye. N. In: Works of the XII All-Union meeting of hygienists, epidemiologists, microbiologists and infectious disease specialists. M., 1959, 323.


Medved', L. I., Trakhtenberg, I. M. Subjects of reports of the fifth all-Ukrainian meeting of hygienists, epidemiologists, and infectious disease specialists. K., 1945.


Medved', L. I. Toxicology of organs affected by mercury, K., 1946.


Melekhina, V. P. Hygiene and Sanitation, 1960, 7, 71.


Minchenkov, Ye. Ya. Physics in the schools, 1950, 2, 42.


Navrotsky, V. K. Industrial hygiene, 1928, 3, 34.


Navrotsky, V. K. Hygiene and Sanitation, 1960, 6, 22.

Navrotsky, V. K. Hygiene and Sanitation, 1965, 12, 76.


Nepesov, A. A. Certain physiological properties of mercury as a microelement. Author's abstract of cand. diss. Ashkhabad, 19

Nepesov, A. A. Health protection of Thurkmenistan 1959, 1, 35.


Nikonets, I. F. Industrial hygiene and occupational diseases, 1959, 4, 52.

Nistratova, S. I. In: Thiol compounds in medicine. K., 1959, 89.


Orlova, A. A. Cardiac activity changes in patients with lead and mercury poisoning (electrocardiographic data) Author's abstract cand. diss. M., 1953.


Pavlov, I. P. Twelfth experiment on the objective study of higher nervous activity, 6, M., 1938.

Pavlov, I. P. Complete collected works, 1, 2, M., 1951, 525 - 564.

Pavlov, I. P. Complete collected works, 3, 2, M., 1951, 267.


Pasynskiy, A. G., Beliteer, V. A. Advances in modern biology, 1953, 36, 2, 236.

Pakhomychev, A. I. Hygiene and sanitation, 1960, 11, 77.


Petrova, N. I., Simonova, N. V. Industrial hygiene and occupational diseases, 1961, 9, 44.


Petrun'kin, V. Ye. In: Thiol compounds in medicine. K., 1959, 7.

Plisetskaya, S. Hygiene and sanitation, 1924.0, 5, 24.

Pokrovskiy, A. A. Advances in biological chemistry, 1962, 4, 61.


Polezhayev, N. G. Hygiene, safety and labor pathology, 1933, 5 - 6, 159.

Polyak, V. Ya., Orlovskaya, A. M., Petrova, N. F. Laboratory affairs, 1958, 1, 47.

Portugalov, V. V., Yakovlev, V. A. In: Thiol compounds in medicine, K., 1959, 83.


Pravdin, N. S., Kremneva, S. N. 1939, 3, 3.


P'yankov, V. A. Subjects of reports of the first Ukrainian meeting of industrial physicians K., 1936, 147.

P'yankov, V. A. Hygiene and sanitation, 1948, 8, 19.

P'yankov, V. A., Loyevskiy, M. P. Industrial hygiene and safety technology, 1936, 6, 57 - 58.


Rozenbaum, N. D. Industrial hygiene, 1923, 1-2, 22.


Rosengard, V. I., Belen'key, M. L. Advances in modern biology, 1949, 28, 3, 387.

Russkikh, Va. A. Subjects of reports of the first all-Russian meeting of hygienists and sanitation physicians, M., 1960, 70.


Ryzhkova, M. N., Smirnova, M. I. Industrial hygiene and occupational diseases, 1961, 6, 34.

Rylova, M. L. In: Investigations in the field of industrial toxicology. L., XII, 1948, 75.


Sakeyev, V. S. and Skorokhodov, P. M., Combatting mercury vapor at a transformer substation of a municipal electric transport net. M. 1952.


Sakhnovskiy, Ya. D. Works and materials of the Ukrainian Institute of Labor Medicine, 3. Izd-vo "Nauchnaya mysli, 1926, 92.

Senkevich, F. P. Hygiene and sanitation, 1950, 1, 55.

Sidorov, S. M. Health protection in Kazakhstan 1942, 7, 49.
Sklyanskaya-Vasilevskaya, G. L. and Yerofeyev, F. N. Hygiene and health 1941, 3, 40.
Smirnova, N. G. Materials on problems of industrial hygiene and clinical aspects of occupational diseases, 7. Gor'kiy Scientific Research Institute of Industrial Hygiene and Occupational Diseases MZORSFSR, Gor'kiy, 1957, 109.
Smirnova-Zamkova, A. I. Archives of pathology, 1946, 4 - 6, 3.
Spynu, Ye. I. Hygiene and sanitation, 1959, 11, 26.
Stoyanskiy, A. F., Rasskazova, T. V. Hygiene and sanitation, 1961, 10, 70.
Syroyechkovskiy, Ye. Ye. Hygiene, safety, and labor pathology, 1933, 4, 36.
Telishevkaya, Ye. N. Collection of scientific and practical works of the Ukrainian industrial sanitary inspectorate, K., 1941.
Tolgskaya, M. S. Morphological changes in the nervous system in certain occupational poisonings. Author's abstract doct. diss. M., 195.
Trakhtenberg, I. M. Pharmacology and toxicology, 1951, 1, 48.
Trakhtenberg, I. M. Physicians affairs, 1959, 2, 171.
Trakhtenberg, I. M. In: Certain philosophical problems of medicine and knowledge, K., 1960, 329.
Trakhtenberg, I. M. Herald of the AMS USSR, 1960, 8, 30.
Trakhtenberg, I. M. Laboratory affairs, 1962, 8, 18.
Trakhtenberg, I. M. Hygiene and sanitation, 1962, 9, 17.


Trakhtenberg, I. M., Gimadeyev, M. M. Physicians affairs, 1963, 6, 103.


Trakhtenberg, I. M., Savitakiy, I. V. Industrial hygiene and occupational diseases, 1965, 12, 7.

Trakhtenberg, I. M., Trinus, F. T., Savitskiy, I. V. Physiological journal, 1963, IX, 6, 748.


Turovskaya, F. M. Hygiene and Sanitation. 1956, 1, 53.


Fidel'man, F.M. Industrial hygiene and occupational diseases 1965, 7, 56.


Fol'bort, O. B. Status and goals of the Ukrainian scientific council I. R. Pavlov. K., 1950, 10.

Frantsuzova, M. A. In: Works of the jubilee scientific session of the Leningrad Institute of Industrial Hygiene and occupational diseases. L., 1940, 321.

Fridlyand, I. G. On the so-called nonspecific effect of industrial poisons, M., 1957.

Fridlyand, I. G. Hygiene and Sanitation, 1959, 8, 55.


Frumina, L. M. Kazan medical journal, 1936, 4, 408.


Khokhlova, R. S. Subjects of reports of the scientific session of the Novosibirsk scientific research institute. Novasibirsk, 1956.

Khrustaleva, V. A., Shalya, N. O. Hygiene and sanitation, 1950, 9, 22.


Chayka, E. I. People's medicine, 1939, 10, 32.


Cherkes, A. I. Basic toxicology of combat contamination substances, K., 1939.

Cherkes, A. I., Luganskiy, N ( I. Physicians Affairs 1957, 1, 6.

Cherkinskiy, S. N. In: Sanitary protection of waterways from contamination by industrial sewage. M., 1954, 68


Shalyt, S. S. In: Works of the jubilee scientific session of the Institute of Industrial Hygiene and Occupational Diseases, L., 1940, 316.


Shakhbazyan, G.Kh., Trakhtenberg, I.M. Hygiene and sanitation 1965, 9, 8


Shnol', S. E. Problems of medical chemistry, 1955, 5, 1, 327.

Sholts, Kh. F. Biochemistry, 1964, 22, 4, 577.


Erisman, F. F. Russian thought, 1883, 2, 38.


Yavorovskaya, S. F. Hygiene and sanitation 1950, 11, 22.


Yavorovskaya, S. Hygiene and sanitation 1952, 12 35.

Yavorovskaya, S. Hygiene and sanitation 1965, 238-241.


Yakovenko, M. V. Hygiene and sanitation 1953, 6, 49.


Borinski P. Deutsche med. Wchschr., 1931, 57, 1060 - 1061.
Brigatti L. H. La medicina del lavoro, 1949, 40, 10, 233.
Cannon W. Physiology of emotions (translated from English) L., 1927
Flury F., Zernik F. Harmful gases (trans. from German) Chemical literature editors of GÖNTINKTP 1938
Singer B. Fraenkel - Conrat H. Biochemistry, 1962, 1, 852.
Starkenstein, E., Rost E., Pol S. Toxicology (from German) I.M - L., Gosmedizdat, 1931.
Stock A. Biochem. Zeitschr., 1929, B. 216, H. 1 - 6, 243 - 248
Stock A. Arch. f. Gewerbepathol. und Gewerbehyg., 1936, 7, 388 - 413.
Stock A. Biochemische Zeitschr., 1940, 304, 73 - 80.
Suzuki T. et al., Industrial Health., 1967, 5, 149.
Werner S. C. The Thyroid 1955.
INDEX

Academic institutions, mercury persistent in, 81
Academic mercury use, problems of, 274-276
Accumulation and distribution of mercury in the body, 41-44
Acetycholine formation and tissue response, 203
Acrocyanosis, 131
Adaptation mechanisms, hormonal influences on, 188
Adaptive syndrome, general, 188
Adhesives for mercury-proof floors, 253
Adolescent health and behavior affected by mercury, 93
Adrenal glands
  activity of rats", 188, 189
  mercury, and, 187
  morphological changes in, 235, 236
  thyroid glands, and, link between, 189
  weight change of, 227
Adynamia in animal studies, 139
Aerial mercury
  content determined by structural contamination, 107
  dental and stomatology offices, in, 86-87
  exclusion of possibility of contamination by, 247
Age and asthenic-vegetative syndrome, 114
Age data in micromercurialism study, 111
Agglutinin titer changes in immunological studies, 217
Agitation, 225
Air
  circulation at industrial sites, 10, 11
  movement insufficient at mercury rectifier sites, 71
  saturated with mercury vapors, 24, 25, 26
  temperature increases, dangers of, 71
  volume requirements and mercury vapors, 11
Albuminates
  mercury, 39
  mercury soluble, 16
Alkylmercurics, unique position
  of among organomercurials, ix
Amalgams
  copper, mercury content in air of production shop
    for, tabulated, 89
  dental, danger from, 83-90
  multiple heating of, 88 Amidochloride, mercury, 60
Amino acids, radioactive, experiments with, 149-150, 152
Analysis of dental and medical office air, 85
Anamnesia studies, 114
Anemia, hypo-chromic, 122
Animal studies on mercurialism, 135-148
Animal tissue protein studies, 149-150
Antibodies activity changes, 223, 224
Antibodies and mercury poisoning 278
Antigas filters, 255, 257
Antiseptic, mercury chloride used as an, 83
Apartments
  See Living quarters
Arc spectrum of mercury, 7
Arterial hypotension, 199
Arterial pressure, increased, 116, 119
Ascorbic acid
animal adrenals, in, 188
liver in, determination of, 152
Assembler of measuring devices case history, 132
Assembly production and air contamination, 58
Asthenia
acute, 5
mercury-induced and other, symptomatic differences, 114
Asthenovegetative syndrome, 108 age and frequency findings, 114, 115
frequency and employment length, 115
sex differences, 114
Asthma, 2
Atmosphere, mercury in the, 20, 22, 96-98
Atrioventricular blood flow, slowing of, 205
Austrian accident causing mercury poisoning, 3
Autoradiography used in brain mercury study, 166

B
Bactericidal effect of mercury chloride, 16
Bandage production with mercury, dangers of, 59, 60
Barriers, mercury, ineffective, 107
Basic sources of contamination
at mercury rectifier sites, 72
Behavior, animals', in laboratory studies, 136, 139, 141
Benzene, poisoning from, 6
Bilirubin content measurements, 122
Biochemical analyses, use of mercury in, 247
Bioelement, mercury as a, 30-35
Biological laboratories, mercury used in, 82-90
Biological significance of mercury as trace element, 30, 33
Biosynthesis of tissue protein, 149, 150
Biphesic reaction in immunological study, 217, 223
“Black mercury,” 260
Blood
blood-lymph mercury feedback, 237
changes in animal studies, 139, 141, 142
dynamics of mercury in, 160, 164
experimental animals, of, mercury in, 144
mercury circulating in, 39
protein changes in animal studies, 150
serum changes in immunological studies, 217, 221, 222, 223
Blueprint shops, mercury used in, 66-67
Body distribution and accumulation of mercury, 41-44
Body weight in animal studies, 136
Bone marrow changes in mental animals,
Bradycardia, 200, 201, 206
Brain
autoradiography and mercury disposition in the, 166
cell composition in mice in laboratory studies,
tabulated, 143
changes in animal studies, 226-227, 228
dystrophic changes in, 242
mercury accumulation in, conditional reflex
activity and, 182,184,185
morphological changes in, 235, 236
presence of mercury in, 41
prolonged exposure to mercury and the, 164, 166
sulfhydryl depression during animal studies, 164, 166
Breakage of medical thermometers, pollution-causing, 83
Brown-Bovery rectifiers, 73
Building, industrial, migration of mercury hazard in, 99-101
Building materials, mercury vapors absorbed by, 24
Building trades, mercury used by, 67

C

Cachexia, xviii
Calibration of thermometers a risky operation, 55
California, discovery of mercury in, 1
Calomel, 15
dangers of production of, 60
Capillary endothelium dystrophy, 204
Carbon, mercury’s relationship to, 16
Cardiac activity and mercury, 199–210
Cardiac function, disturbed, mercury’s effect on, 33
Cardiac rhythm changes produced by outside agents, 201
Cardiac sensitivity and vagus nerve influence, 203
Cardiac symptoms in animal mercury studies, 200
Cardiotoxic effects of mercury, 199–210, 281
Cardiovascular activity
changes, determination of degree of, 208
changes in micromercurialism, 110
Cardiovascular changes, xxi
Cardiovascular insufficiency, 133
Cardiovascular lability, 116
Cardiovascular reactive capability limited by exposure to mercury, 208
Cardiovascular system changes under mercury, 204
Carrier a ship of mercury, 48 Case histories in micromercurialism, 131–133
Catalytic properties of mercury, 7
Catarrhal symptoms, 109
Cats, suitability for conditional reflex activity, 167
Cement floor, contamination of, 107
Central city, high mercury concentrations in, 97
Central nervous system
changes in chronic mercury poisoning, 167
changes in micromercurialism, 203
diet benefiting, 269
disturbance, asthenic, 108
effects of micromercurialism, 110
mercury traces in, 43
microstructure differences, 166
shifts, effects of, 280
Ceramic floor tiles, mercury-proof, 253
Cerebral cortex affected in mercury poisoning, 167
Charcoal, activated, and mercury absorption, 22
Chemical analyses, mercury compounds used in, 83
Chemical environmental factors causing disease, 277
Chemical factors and cardiac activity, 199
Chemical properties of poison and organ of excretion differences, 46
Chemical structures and toxicity relationships, 17
Chemical viscose factory, aerial mercury persistence at, 107–108
Chemicals, demercurizing See Demercurization
Chemistry classrooms
locations, 91
mercury vapor analyses of, 90–91
Chemoreceptors related to
tissue receptors, 199
Chlorine combined with mercury, dangers of, 74
Chloroalbuminates formed in stomach, 39
Cholinesterase activity inhibition, 181
Chronic experiments, xxv Chronic poisoning
prophylaxis, 243–270
vapor concentrations and, 49–50
Cinnabar, 15
extraction of, 53-55
native deposits of, 20 Circulation of mercury in working premises, 105 Circulation of mercury in body, 38-41
Circulatory changes, 208
See also Cardiotoxic effects of mercury
Cities, mercury vapor occurring in, 23
Classical mercurialism, symptoms of, xviii
Classrooms
location of, 276
mercury in, 90-96
vapor content, tabulated, 92 Cleaning methods, anti-mercury, 260, 261, 262
solution used in Kiev Hospital, 85
workers’ clothing, of, 255-257
Clinical observations of micromercurialism patients, 130
Clonic seizures in animal studies, 140
Clothing, protective, 255
Coal, mercury in, 23, 97
Coal mine, vapor in air at, 54
Coatings, mercury-proof, 249-251, 252
Cobalt oxide, 22
Coefficient of diffusion for mercury, 11
Colorimetric analysis, 265
Common diseases and industrial conditions, xiii
Complement activity of blood in immunological studies, 217, 223
Compounds of mercury
industrial, xix
serious poisoning from, 4
Computers, mercury used in, 66 Concentration maintenance procedures in animal studies, 136
Concentrations measurements at industrial sites, 99-108
Concrete, mercury-proof, 253
Condensation sites of mercury vapor, 10
Conditional motor reaction development, 167
Conditional reflex activity
animals used in studies of, 167
cats used in study of, 167-186
chronic experiments, 182
disappearance of conditional reflexes, 182
functional normalization time in, 176
mercury exposure, and, ix, xi, xxi
mercury in brain tissue, and, 182
mercury’s effects on, 167-186
normalization in experiments with cats, 181
reversal of higher nervous activity damage in, 176
subcutaneous administration of unithiol in, 176, 181
thiol administration in, 181
unithiol restoring conditional reflex activity, 182
Conductivity of mercury, 7 Contamination
atmospheric, by mercury, 23, 24
comparisons, laboratory, 80
decline in Kiev Hospital, 85
dental offices, in, 83-90
domestic, 104
schoolrooms, of, 91, 92
secondary, at production sites, 99-108
soil as a secondary source of, 27
sources in laboratories, 271 Conversion of mercury in body, 38-41
Copper amalgams, dental, danger from, 84-90
Corneal reflex lowering, 130
Coronary blood formation disorders, 204
Coronary insufficiency
  acute, mercury poisoning, and, 205
  feelings, 109
  pituitrin, and, 200, 205, 208
Corrosive sublimate, 13, 60
Cortical inhibition in cats CNS studies, 172
Cortical neurodynamic changes of phasic character, 133
Cortical-subcortical interaction changes, 131
Cyanides, mercuric, 16

D
Dangers from school demonstrations with mercury, 95
Decrease in poisoning incidence, 5, 6
Degassing, mercury loss during, 104, 106
Degenerative changes caused by exposure to mercury, xiv
Demonstrations, schools, requirements for, 95
Demonstrations with mercury, and aerial content measurements, 93, 94
Demercurization, 99, 257, 260, 261
  not effective, 93
  printing plants, of, 66
  radical, 103
  thermic, 262
  sulfur, with, 262
  unsuccessful, 107
Denaturation of proteins, 157
Dental caries and mercury pollution, 29
Dental offices
  industry contamination comparisons, 88
  hygienic investigations of, 84
  mercury content, tabulated, 86-87
  precautions to be taken in, 246
Dental work, danger from, 83-90
Deposit sources classification 108
Depot organs, destructive changes in, 237
Depression, mental, 109
Derivatives of mercury, organizations using, 51
Detectability of mercury vapor in, 8
Determination of mercury, accuracy of methods for, 41
Detoxification with mercury chloride, 34, 35
Diagnosis
  early, of micromercurialism, 109
  industrial poisoning of, 6
Dianostic quantities of mercury, 31
Diarrhea, 109
Diet, therapeutic-prophylactic, 269
Diethylmercury, 17, 18-19
Dihydroascorbic acid reduction, 152
Dilution of secondary contamination sources, 103
Diphtheria, experimental, and mercury chloride administration, 34, 35
Discharge of mercury from industrial plants, xix
Diseases
  aggravated by mercury, 268
  mercury pollution, and, 29
Diseases of Artesans, 1, 2
Disinfectant
  ethylmercuric phosphate used as, 67
  power of mercuric chloride, 13
  Distribution dynamics of mercury in organs, 237
Diuresis, decrease in mercury poisoning, 42
Dizziness, 130
DNA solutions, mercury and, 35
Domestic mercury contamination, 104
Drying of mercury by heating, 75
Dynamia, 225
Dynamic and adynamic states in animal CNS experiments, 172
Dystonia, vegetative-vascular, 108 Dystrophy
  myocardium, of, 204
  parenchymatous, 152

Earth’s surface, mercury concentrated in, 24
Economics of replacement of mercury in industry, 244
Electric heat generating station, secondary contamination at, 104
Electric light manufacture dangers in, 56-59
Electric power stations, mercury pollution and, 63
Electric transport, increases in use of, 67
Electrical activity, cardiac, animal experiments in, 205
Electrical medical thermometer replacing mercury instrument, 246
Electrical transformer sub-stations, mercury in air of, 67
  working conditions at, 70-71
Electrocardiographic studies in animal experiments, 200, 201, 202, 205
Electrodes, calomel, replacement by silver electrodes, 245
Electrolytic chlorine production, 68, 73
Electron microscopy and contamination, 81
Electronic data processing machines, mercury used in, 66
Electrovacuum production and poisoning risks, 56-59
Emotional instability, 93
Emotional sensitivity, 118
Encephalopathy, mercurical, 48
Endocrine gland regulation and toxic substances, 187
Endocrine glands changes in micromercurialism, 110
England, mercury poisoning in, 3
Entry route of mercury into body, 37-50
Environment
  contaminated, of dental offices, 84
  external, mercury content of, 22
  geochemical data on mercury in the, 19-30
  mercury in the habitational, 1-6
  mercury vapor in, tabulation of, 26
  mercury’s distribution in, 7-35
  studies of mercury content of, 244
Environmental pollution
  See Pollution, environmental, ix
Enzymatic functions and mercury, 166
Enzyme poisons, 279
Enzyme processes blocked by mercury, 33, 35
Enzyme systems activity changes, ix, 223
Eosinophilia, 122
Equipment, medical, mercury used in, 83
Erethism, mercury, xviii, 108, 133
Erythrocyte counts, 122
Ethyl gasoline, poisoning from, 6
Ethylmercuric chloride, 17-18
Ethylmercuric phosphate, 18
Ethylmercury compounds
animal studies, in, 182, 184, 185
brain changes, and, 227
Etiology, mercury poisoning, 113
Evaporation
mercury entering atmosphere by, 22
temperature control, and, 260
Examinations, medical, mercury-workers’, 268
Excretion of mercury, 44-49
differences, in, routes of, 45
urinary, 123
Excretory organs, mercury retained in, 42
Exhaled air and mercury excretion, 47
Exhaust hoods
dental offices, in, 85
illustrated, 256
value of, 98
Experimental mercurialism, proteinemic shifts in, 149- 166
Experimental prevention of micromercurialism, 243
Experiments with mercury, dangers from, 90
Explosives, mercury fulminate, used in, 14-15
Extensor strength studies, 127- 129
Extraction and smelting of mercury, dangers in, 52
Extremities, paralysis of, 225 Eyelid tremors, 79

F
Factories
See also Industrial sites mercury content sampling in, 102
Factors impairing worker’s health, xvii
Fallow mercury, 84
described, 93
working premises, on, 99
Faraday’s use of mercury, 5
Favor gas system analyzer, 81
Feces
basic mercury excretion route, 45
experimental animals of, mercury in, 144
human, mercury content of, 31
Felt manufacturing, mercury used in, 3, 4
Ferric chloride, 101
demercuration, in, 260
Ferricyanide method of protein study, 158, 164
Filters, types used in mercury operations, 255, 257
Filtration of mercury, 75 Floor coverings, mercury-proof
See Coatings, mercury-proof
Food products’ mercury content, 31, 32, 33, 34
Formaldehyde, 82
Formvacuum pumps, and mercury vapor release, 68, 70
“Free” mercury in blood, 39
Fuels, mercury in, 23, 97
Functional changes in micromercurialism, 110
Functional depression caused by mercury, 43
Functional disturbance and toxic substances, 187
Functional shifts
cased by micromercurialism, 225
of heart caused by mercury, 204
Fungicides, 17
Furniture, contaminated, 264

G
Gas analysis equipment, 80
Gas analyzers, mercury, replacement by other types, 245
Gas laboratory, mercury used in, 104, 106
Gastrointestinal tract, mercury entering, 37, 38
Geochemical data on mercury in the environment, 19-30
Geohygiene, a new branch of hygienic science, 27
Germany, mercury poisoning in, 3
Gingivitis, 55, 90
Glandular enlargement, 127
Glass
   containers, mercury stored in, 76
   danger from breakage of, 61
   stoppers and mercury storage, 271
   valves, mercury contamination through, 75
Goiter, endemic, 30
Gonadotrophic effects of mercury exposure, 235
Gorno-Altay Autonomous Region Studies, 29
Hair follicles, mercury entering, 38
Hand tremors, 132, 133
   See also Tremors
Handlers of mercury, micromercurialism in, 109-134
Hazards from mercury use in schools, 90-96
Hazards, specific, in mercury use, 51-52, 54
Headaches, 130
Health and occupational activity, 277
Health improvement procedures in pharmaceutical industry, 60, 61
Health of population and mercury’s atmospheric presence, 29
Heating of mercury, dangers of, 62
Hematological shifts, 108
   experimental animals, 139, 141, 142
Hematological studies in micromercurialism patients, 119-122
Hemoglobin increases, 122
Hepato-toxic effect of mercury, 46
Hermetic sealing of mercurial processes, difficulty of, xiv
Hermetization of feed in mercury, processes, 248
Higher nervous centers, mercury’s effects on, 181
Histochemical research, mercury compounds used in, 83
Hormones
   activity changes, 223
   hormonal functions and mercury, 166
   insufficiency, 197
   pathological processes, and, 187
   responses to mercury, ix
Human habitat, chemical factors’ geohygienic significance in, 29
Human organism, mercury occurring in, 19
Human organss mercury content, 31
Humans as. a social unit, the health of, 135
Hydrocarbon content in air, 97
Hydrosphere, evaporation of mercury from, 20
Elygienic evaluation of mercury content, 20
Elygernic properties of earth’s surface, 27-28
Elyperthermia, 10
Flyper-salivation, 131
Hyperthyroid goiter, 30
Hyperthyroidism, 192
Rypophyseal-adrenal cortical system
   animal studies on, 188
   functional shifts in the, 187-197
   mercury exposure, and, ix, xi, xx1
Hypotension, arterial, 199
Hypotonia, 116
Hypoxia, 242
  myocardial, and coronary spasm, 208

Illness severity and mercury excretion, 48, 49
Illuminating gases, mercury in, 23
Immune reactions to mercury, ix
Immunobiological reactivity, animal experiments on, 212
Immunological reactivity changes occur early in toxic aggression, 224
  industrial environmental factors, and, 211
  lability of, 279
  mercury influences, and, 211-224
  serving as indicator of body strength, 211
  two periods of, 217
Immunological functions and mercury, 166
Immunological properties and low mercury concentration, 211
Impotence, 130
Industrial conditions affecting course of common diseases, xiii
Industrial discharge of mercury vapors, 24, 26
Industrial environment and the human body, xviii
Industrial establishments, mercury present in, 63
Industrial hygiene, importance of, xvii
Industrial hygienic criterion, not suitable for schools, 91
Industrial processes and mercury contamination, 117-118
Industrial production and mercury intoxication, 51-62
Industrial regions, mercury in atmosphere of, 97
Industrial sites
  contamination in medical effects study, 111
  free of previous mercury operations, measurements at, 103
  secondary contamination at, 99-108
Industries using mercury list of, 51
  number of, 53
Infectious diseases
  cardiac rhythm changes, producing, 201
  mercury pollution, and, 29
Infestations, mercury used against, 2
Influenza and mercury excretion finding, 123
Influenza and micromercurialism, differential diagnosis, 13-
Inhalation exposure in animal studies, 135
Inhaled mercury excreted in urine and feces, 45
Inorganic compounds of mercury, 13-16
Insomnia, 118
Instability of inorganic mercury salts, 16
Instrument building and mercury poisoning, 55-56
Instrument manufacturing plant, observations at, 99
Instrument purification and vapor increases, 80
Instrument Testing, Bureau of, 66
Instruments
  mercury-filled, plexiglass cabinet for, 248
  mercury used in, 4
  processes using mercury, list of, and, 51-52
Intellectual capacity decline, 109
Intersignal times detection in cat CNS studies, 167
Intestinal disturbances, 117
Intestine’s mercury content in intoxication, 42
Intoxication
  course of, and blood mercury content in animal studies, 144
  industrial production and, 51-62
mercury excretion relationships, and, 48, 49
mercury, with, 37
specific, protection needed against, 70
lodides and biomides of mercury, 15
Iodine, low concentration in study region, 30
Ionization potential, 13
Irritability, 109
Irritants, effects of low levels of, 278
Isolation of metallic mercury in industrial building, 248
Isolators used in rectifier mercury condensate zones, 73
Italy
discovery of mercury in, 1
workers’ demands in Tuscany mine incident in, 3

K
Karocytosis, 182
Kazan, electric transformer stations in, 72
Kidneys
deposition of mercury in, 41, 42
morphological changes in, 227, 228, 229
Kiev
electric power station at, 65
mercury in atmosphere of, 96
Kjeldahl protein study method, 158
Kollen dynamometer used in muscle function tests, 127, 128, 129

L
Labor conditions in laboratories using mercury, 74
Laboratories
mercury poisoning at, xx
mercury vapor in, 80
operations, universal character of, 74
prevention of mercurialism in, 271-276
prophylactic isolation of, 248
vapor concentration data, of, 77, 78-79
worker contact with mercury and, 74-82
Laboratory animal studies of mercury poisoning, in, 135-148
Laboratory – industrial concentrations comparison, and, 82
Langmuir pumps, 271
Lead poisoning, 6
Length of exposure in mercury poisoning study, 112-114, 115
Lethal dose of soluble mercury salts, 50
Leukopenia, 122
Levels of mercury permissible in various countries, 285
Lighting equipment
manufacture of, dangers in, 56-59
mercury used in, 7
Liquid layer, mercury penetrating, 271-272
Lithosphere, mercury in, 22
Liver
damage to, xviii
diet benefiting, 269
function changes, 116, 117
function disorders and protein synthesis, 150, 151
mercury remaining in, 42
morphological changes in, 230
proteins study, 158, 165
sulfhydryl content in, tabulated, 165
Living quarters
contamination of, 106
dental offices, with, 107
mercury content of, 106
Low blood pressure, 119
Lucretius, 2
Luminescent bulbs manufacture, dangers of, 56–58
Lungs, the
  lung tissue resynthesis in animal studies, 164
  mercury excretion by, 47
  mercury vapor absorption by, 39
  morphological changes in, 227, 229, 231
Lymphocytosis, 122

M

MacLeod mercury manometers replacement by other types, 245
MacLeod vacuumeters, 72
Mammalian organisms, mercury occurring in, 19
Mammary gland excretion of mercury, 46, 47
Manganese deposit, vapor in air at, 54
Manganese dioxide, 14
Manganese oxides, and mercury vapor sorption, 22
Manometers
  air contamination, and, 80
  danger of use of, 65
  mercury-filled, replacement by membrane type, 244
  used widely in power stations, 65
Maximum allowable concentration of mercury, xx
Medical contraindications to working with mercury, listed, 268, 269
Medical departments using mercury, list of, 82
Medical examination of industrial mercury handlers, 88, 90
Medical institutions, mercury used in, 82–90
Medical personnel and mercury contact, 82
Medical practice, mercuric chloride used in, 4
Memory loss, 5
Memory weakening, 109
Mercurialism
  handlers of mercury, in, 109–134
  hazards in schools, 90
  occupational, xi
Mercuric chloride, 2, 13
  as a detoxifying agent, 34, 35
  bactericidal effect of, 16
Mercuric oxide, 60
Mercuric sulfide, cinnabar, 15
Mercurophene, 16
Mercury
  absorption of, 19
  amidochloride, 60
  atmosphere, in the, 20, 96–98
  basic bodily depots of, 42
  benzoate, 60
  bioelement, as a, 30–35
  Brown-Bovery rectifiers, escape from, 73
  concentrations higher than normal for tissues, significance of, 35
  contamination in dental office, tabulated, 89
  cyanide, 60
  demonstrations in schools, requirements for, 95
  depots in body, 41
  derivatives of, 13
  detection, ix, x
  development of mercury industry, 1
  diseases and, 29
  distribution in body and accumulation in organs, 41–44
  diffusion coefficient of, 11
early production of, 2
electric power stations, at, 63
electron microscope diffusion pump, in, 81
escape from instruments, 76
excretion of, 44-49
exposure to, vague clinical symptoms in man and, ix
fuel, in, 23
fulminate, 2, 14
danger in manufacture of, 52
food products, in, xxi, 31, 32, 33, 34
general survey of, 7-35
geochemical study of, 19
human organs, in, 31
indispensability of, x
industrial toxin, as a, ix
ingested in suicide attempt, 38
inorganic compounds of, 13-16 intoxication, 37
See also Intoxication
iodides and biomides of, 15
ionization potential of, 13
maximum allowable concentration of, xx
mercury-containing equipment used in laboratories, 74
"mercury hazard," hygienic characteristics of, 74
"mercury locations," cleaning of, 261
"mercury magnet" described, 25
"mercury objects" distribution in urban conditions, 62, 6
"mercury occupations," safety principles in, 61
"mercury professions," the, 268
mercury-proof coatings, 249, 251, 252
mercury-proof paints not used in schools, 95
metallic ancient use of, 1
molecular weight of, 12
monochloride, calomel, 15
nitrate, 60
open and closed work with, 24
organic compounds of, 16-19
organic- inorganic compounds differences, 16
oxides and suboxides of, 14
persistence of contamination by, 85
physical and chemical properties of, xxi
poison against infestations, a,2
poisoning, chronic, 78
production data table, 21
production of, 53-55
prolonged exposure to, 118
relationship with other toxins, x
replacement by other compounds, xv iii
rings, substitution by rubber, 245
street dust, in, 23
streptomycin production, used in, 61
sulfide ointment poisoning by, 38 surface tension of, 11
toxic doses and concentrations of, 49-50
urban conditions, in, 63-98
urinary excretion absence of, ix
vapor in air samples, 24, 25
various concentrations in animal studies, 135-148
viscosity of, 12
V-manometers, replacement by other types, 245
water sources in, 29
why is it used?, 7
workers affected by small concentrations of, xiii
Mercuryless instruments recommended for schools, 274
Metabolism of proteins, 166
    See also Tissue protein studies
Metabolism, mercury's part in, 33
Metal salts, detoxifying capabilities of, 35
Methionine, radioactive, in tissue protein studies, 149-150
Methoxyethylmercuric acetate, 17, 18
Mexico, discovery of
Micromercurialism
    mercury in, 1
    age data in, 111
    arterial pressure increased in, 116
    case-histories in, 131-133
    CNS changes in, 203
    clinical-statistical study of, 110, 111
    definition of, xx
    diagnosis of, 109
    differential diagnosis, 133-134
    etiology, 134
    experimental, 181
    experimental prevention of, 243
    exposure length and appearance of symptoms, 119
    functional changes in, 110
    functional shifts caused by, 225
    handlers of mercury, in, 109-134
    hazard in school environment, 93
    hormonal shifts and, 197
    immunobiological reactivity and, 211-224
    immunological indices and, 213
    latent effects of, 117
    length of exposure in, 112-114
    mimicked by conditioned reflex activity changes, 181
    morphological changes in, 229

N
Nerve endings metabolism affected by mercury, 199
Neuralgia and neuritis, 116
Neurodynamic changes, cortical, 133
Neuroendocrine degeneration, 93
Neurological symptoms, 130
Neuromyalgia, 132
Neurotic disturbance, 242
Neurotic phenomena, 133
Neutrophil changes in animal study, tabulated, 215
Newborn, mercury poisoning in, 46
Nitric oxide of mercury, 14
Nitric suboxide of mercury, 14
Nitrogen compounds of mercury in schools, 91
"Nonspecific" syndrome in micromercurialism, 117
Nystagmus, horizontal, 130

O
Occupational disease clinics, observations at, 130
Occupational intoxications and prophylaxis, 82
Occupational mercurialism, 2, 52
    problem, the, 63
Occupational origin of micromercurialism symptom complex, 118
Ointments, mercury, 60
Olfactory sensitivity changes, 108
Olfactory sensitivity studies, 124-125
Open and closed work with mercury, 24
Organ changes, morphological, 225-242
Organ weight in animal studies, 226
Organic derivatives of mercury, industrial synthesis of, 19
Organic mercury derivatives, 16-19
          cumulative tendencies of, 226
Organic residues and mercury, and toxic effects, 17
Organic substances analysis with mercury, 7
Organomercuric compounds, 17
          intact after causing animal’s death, 40
          toxicological study of, xiv
Organophosphorus poisoning, 181
Organs, gross examination at autopsy, changes found in, 227
Ovaries, morphological changes in, 235, 236
Oxidation-purification of mercury, 75
Ozone oxidation of mercury, 75

Paints, mercury-proof
          See Coatings, mercury-proof Paralysis, 2

Paresis, 225
          of mouse extremities in animal studies, 139, 140
Partial vapor pressure of mercury, 8
Pathogenesis of reactions to toxic compounds, xviii-xix
Pathological changes in organs and tissues are reversible, 237
Pathomorphological changes occurring first, 242
Penetration of mercury into building components, 107
Peptide chains denaturation, 160
Perchlorovinyl resin, mercury-proof, 253

Pesticides, 17
Phagocytic activity of blood in immunological studies, 223
Phagocytic drop in immunological response studies, 212, 213
Pharmaceutical production with mercury, dangers of, 59-62
Phenylmercuric bromide, 17, 18
Physician, industrial, and contamination encounters, 104

Pharmacology
          Physicians, industrial, and contamination encounters, 104
          mercury vapor in, 90, 92
Pharmacological norm of mercury, determination of, 30-31, 33
Physiological variation, 282
Pilomotor reflex changes, 131
Pituitrin and coronary insufficiency, 200, 205, 208
          injections in animal studies, 208
Plants, industrial, and mercury content of environment, 24, 25, 26, 27
Plasma collection and testing in animal experiments, 152-154
Plasma proteins’ reactive capability tests, 154
Plaster of apartments, mercury measurements in, 106
Pneumatic cleaning of glass containing mercury, 62
Podolsk district, massive mercury poisoning in, 2, 3
Poison does not always prove toxic, 284
Poisoning
          determination of urinary mercury, and, 47, 48
          experimental, dosages used in, 50
          mercury used in medical practice, and, 4
          two phases of, 280

Poisons, industrial, immunological response to, 211
Polarographic determinations of chemical elements in laboratory, 81
Pollution, environmental, ix
Polyneuritis, xviii
Potassium permanganate in demercurization, 101 261
Precautions absent in schools, 95
Precipitation of mercury into body parts, 42
Preparatory schools, mercurialism hazards in, 90
Pressure devices, contamination from, 76
Pressure of vapor and vapor tension with temperature increases, tabulated, 9
Prevention of mercury’s effects, 243-270
Preventive measures, xiv, 5, 70
Printing processes, dangers in, 65-66
Procedures in animal studies, 136
Production of mercury, tabulated, 21
Production increase, mercury, 20
Production sites, secondary contamination at, 99-108
Products in which mercury is used, list of, 51-52
Professional status of micromercurialism patients, tabulated, 112
Properties of mercury, described, 7
Prophylaxis chronic mercury of, 243-270
Prophylaxis mercury’s entry 37
poisoning, route, and, occupational intoxication, of, xiv, xx
Protective coatings, efficiency of, 107

Protein
granular dystrophy, 227
metabolism shifts, 224, 278
resynthesis inhibited by prolonged mercury exposure, 242
tissues in, and the effect of mercury, 149
Proteinemic shifts, 278
chronic experiment animals, in, xxi
experimental mercurialism, in, 149-166
Protoplasmic poisons, 16
Psychic disturbances, xviii
Psychic function changes, 109
Pulmonary depot, mercury’s, 237
Pumps, comment on types of, 76
Purification of mercury, dangers of, 271, 272
Purification of mercury in laboratories, 74-75
Purity of vaporizing mercury, 12
Pyrometallic method of mercury production, 53, 54

Qualitative analysis for mercury presence, 264-265

Rabbits experimental, mercury deposition in, 43, 44
less sensitive to mercury, 226
Radiculitis, 115
Radioactive iodine retention in thyroid dysfunction, 187
uptake in rats’ thyroids, tabulated, 191, 192, 193, 194, 195, 196
Radioactive methionine intensity of uptake by plasma proteins, 157
tissue protein studies, in, 149-150
Radioisotope method of mercury metabolism detection, 43
Reactivity shifts as criterion for hygienic norms, 211
Recontamination of industrial building, 101, 103
Rectifiers, mercury
contamination from, 68
overhaul periods and vapor release, 72
overhauling, dangers of, 68
repair of, 68
replacement by flint type, 244
used in electrical processing, 67-74
Reduction of mercury use as prophylaxis, 247
Reflex activity, conditional, mercury affecting, 167-186
Reflex changes, 130
Reflex excitability, 225
Regulation of mercury use in schools, 274, 276
Reproductive cell changes caused by mercury poisoning, 235
Research industrial poisoning, into, recent, 6
  institutions, mercury poisoning at, xx
Residential areas, mercury in air of, 96-97
Response reactions to mercurial toxicity, xiv
Respirators, anti-mercury, 257
Respiratory discomfort, upper, 109
Respiratory tract as mercury entry route, 37, 39
Resynthesis of tissue proteins, study of, 149-150
Reticulocyte level increases, 122 RNAase and mercury, 35
Route of entry into body of mercury and morphological changes, 226
Russia, discovery of mercury in, 1

Saliva, mercury not observed in, 43
Sanitary Epidemiological Station Moscow, 66
  Odessa, 67
School classrooms
  See Classrooms
Schools, hygienic criterion for, 91
Seals, mercury used in, 76-77
Secondary contamination
  electric heat generating station, at, 104
  production sites, at, 99-108
“Secondary” pollution sources 70
Seeding in animal studies, 135
Seizures, clonic and tonic, 225
Self-confidence loss, 109
Selye, H., view on general adaptive syndrome, 188
Seminal epithelium, morphological changes in, 235
Shale oil, mercury in, 23
Shifts in blood circulation system, 199
Shifts in conditional reflex studies, animal, 172
Shifts, functional, in micromercurialism, 225
Shifts in protein metabolism, 224
Skin as a mercury entry route, 38
  changes in, 131
  symptoms, 116
Sleeplessness, 109
Slow excretion of mercury, 44
Small concentrations of mercury, effects on workers, xiii
Soils mercury in, 22
  secondary contamination source, as a, 27
Solidification of mercury from vapor, 22
Solubility and dissociation, importance of, 16
Solution-purification of mercury, 75
Soot, mercury content of, 23
Sorbed mercury determination of, 265
  in physics classroom, 93, 94
Sorption of mercury vapors, 22
Spain, mercury poisoning in, 3
Spasm, coronary, 208
Specific and nonspecific occupational diseases, prevention of, xvii
Specific gravity of mercury, 7
Spermatogenesis destroyed by mercury, 235
Spills of mercury, collection of, 257
Spleen, morphological changes in, 227, 231
Stability of organomercury compounds, 17
Stephanis instruments, mercury in, 82
Stimuli and reflex activities in cat ONS study, 168
Stomatitis, 45, 79, 90, 117
Stomatology offices hygiene in, 84
  mercury content tabulated, 86-87
Storage of mercury, 272
  in tanks, 76
Storage site vaporization, hazard from, 52
Street dust, mercury in, 23
Streptomycin manufacture, 247
  mercury used in, 61
Stress first-mediator of, 188
  olfactory sensitivity, and, 125
Structural elements, mercury removal from, 101, 103
Structural retention of mercury, example of, 106
Subcortical ganglia affected by mercury poisoning, 110
Substitution of other substances and methods in industry, 244
Sulfhydryl
  content in blood serum, animals, tabulated, 163
  enzyme, inactivation, 204
  groups depression in blood serum, 160
  mercury’s action on, 154
  release of, in protein studies, 158
  the role of, 149, 154
Sulfur in demercurization, 262
Sulfuric anhydride, 96, 97
Surface tension of mercury, 12
Susceptibility, individual, 279
Sweat glands as mercury excretors, 45
  mercury entering by, 38
Symptomatics of micromercurialism insufficiently defined, 109
Symptoms associated with exposure to low levels of mercury, ix
  micromercurialism, of, 109
  subjective, in mercury poisoning study, 113
Th"
reversibility of, changes of, 197
normalization by antidotes, 192
mercury affecting, 187-197
mercury pollution and, 29-30
morphological changes in, 232 233, 234
phasic response to mercury in, 232
sensitivity of, 187
uptake studies, 125, 126, 127
Tissues, the action of mercury on, 149
Tissue proteins effects of mercury, and, 149, 197, 203
mercury reacting with, 197
renewal of, mercury affecting, 149-150
studies, of, 181
Toxic disorders, genesis of, and endocrine function shifts, 188
Toxic doses and vapor concentrations experiments, 50
Toxic substances and functional disturbances, 187
Toxicity and chemical structure relationships, 17
Toxicity and mercury salts solubility, 16
Toxicodynamics of mercury and its compounds, xxi, 37-50
Toxicological differences between organic and inorganic mercury compounds, 41
Trace element, mercury as a, 27, 30, 235
Transformation of mercury in bloodstream, 39, 40
Transformer stations, contamination at, 104
Transmethylation, 157
Treatment of micromercurialism, 269
Trees, mercury vapors absorbed by, 24
Tremors, xviii, 79, 118, 127, 225
Trigeminal sensitivity tests, 124-125
Turk cells' appearance in animal studies, 141
Turkey, mercury poisoning in, 3
Typhoid fever antigen injection, 212

U

Unithiol 1
diagnostic use of, 268
injection in protein studies, 157, 158
normalizing thyroid function, 192, 195, 196
Untypical compounds found in schools, 91
Urban conditions, mercury in, 63-98
Urinalysis and mercury excretion, 47, 48
Urinary and air mercury concentrations, 47
Urinary excretion of mercury, 45, 114
absence of, ix
by smelters, 55
Urinary mercury content analysis, 123
Urination, frequent, 109
Urine experimental animals, of, mercury in, 144
mercury content measured, 30
Uses of mercury objects in urban areas, 63
U.S.S.R. Ministry of Health, vii

V

Vacuum treatment in, 56-59
Vacuometers danger of use mercury vapor 70
processes dangers of, 65
contaminants, as, concentrations of chronic intoxication and, 49-50
data, contradictory on, 77, 78-79
samples in air, 24, 25
determination, devices for, 265, 268
entering air in vacuum process plants, 58
experiments with cats, 167-186
generation by Brown-Bovery rectifiers, 73
lamps, mercury, replacement by other types, 245
mercury, contamination of air with, xiii
mercury, penetrates body pores, 8
poisoning prophylaxis a major concern, 243
Vaporization and temperature increases, 10
Vaporization speed of native mercury in cinnabar deposits, 20
Vaporizing of mercury, 8
Variability of contamination in dental offices, 88
Vascular hypertonia, 119
Vascular permeability affected by mercury, 242
Vegetative disorders listed, 133
Vegetative nervous system, mercury affecting, 93
Viscosity of mercury, 12
Vitamin therapy, 269
Volatility of mercury vapors, 20
Volcanic eruption and mercury vapor, 20

Wxyz

Washing mercury, contamination from, 75
Water sources, mercury levels in, 29
Water stress in animal studies, 189
Weight loss, 225
Weight loss in animal studies, 136-139
Weights and Measures, Division of, mercury instruments used by, 66
White mercury precipitate, 60
Winter-summer air temperature differences, mercury vapor and, 71
Work function, chemical depression of, 280
Workers in micromercurialism study, types of, 113
Workers, medical surveillance of, 268
Working capacity loss in mercury poisoning, 6
Working premises, mercury circulation in, illustrated, 105
Wrist strength comparison studies, 127-129