API TOXICOLOGICAL REVIEW

MERCURY

SEPTEMBER 1948

Note: This review summarizes the best available information on the properties, characteristics, and toxicology of *mercury*. It offers suggestions and tentative recommendations pertaining to medical treatments, medical examinations, and precautionary measures for workers who are exposed to mercury. It was prepared at the Harvard School of Public Health, Boston, Mass., under the direction of Professor Philip Drinker. The review has been accepted for publication by the Medical Advisory Committee of the American Petroleum Institute. Anyone desiring to submit additional information or proposed changes for consideration prior to re-issuance of this review is requested to send them to the American Petroleum Institute.

This review was prepared by Marshall Clinton, M. D.

AMERICAN PETROLEUM INSTITUTE
DEPARTMENT OF SAFETY
50 WEST 50TH STREET
NEW YORK 20, N. Y.

TOXICOLOGICAL REVIEW OF MERCURY*

I. Substance

Mercury, Hg.
Atomic weight=200.61.
Synonym: quicksilver.

II. Properties and Characteristics [1, 2, 3a]

Melting point	=minus 38.89 deg C (−38.1 deg F).
Boiling point	=356.9 deg C (674.4 deg F).
Specific gravity	=13.595 at 4 deg C (39.2 deg F).
Vapor pressure:	
0 deg C (32 deg F)	=0.000185 mm of mercury.
20 deg C (68 deg F)	=0.001201 mm of mercury.
40 deg C (104 deg F)	=0.006079 mm of mercury.
60 deg C (140 deg F)	=0.02524 mm of mercury.
80 deg C (176 deg F)	=0.08880 mm of mercury.
100 deg C (212 deg F)	=0.2729 mm of mercury.
1 mg per liter	=122.7 ppm; 100 ppm=0.820 mg per liter.

Concentrations of mercury are generally expressed in mg per cubic meter of air rather than parts per million, as mercury is often present in particulate form, as well as in the vapor phase.

Mercury is a heavy, silvery white, shining metal which is liquid at ordinary temperatures. It is a fair conductor of heat and electricity, and has a regular coefficient of expansion. It tarnishes but slightly in air except when heated to near the boiling point, where it is slowly converted to the oxide (HgO) from which the oxygen is set free at higher temperatures. Mercury will dissolve many metals, with which it forms amalgams.

Mercury metal is insoluble in water and organic solvents, but is soluble in nitric acid. Mercurous nitrate is formed in the presence of an excess of mercury, and mercuric nitrate in the presence of an excess of nitric acid.

Clean droplets of metallic mercury coalesce readily to reform larger drops or pools of the metal, but dirty or greasy droplets do not rejoin easily. Small amounts of mercury spilled on benches or floors tend to become increasingly finely subdivided. This presents an increasingly large surface area per unit volume of material at which vaporization can take place and, in addition, dust stirred up from such areas may contain considerable quantities of finely divided particulate mercury which will settle from the air gradually because of their extremely small size.

III. Probable Sources of Contact [4]

Mercury is extensively used throughout the petroleum industry in instruments such as manometers, flow meters, thermometers, level regulators, and similar equipment. Its use is most widespread in the laboratories, where it is used in a wide variety of scientific instruments and as a confining or leveling liquid in sample tubes or gas-analysis apparatus.

Contact with mercury may occur in association with any of the foregoing uses, but dangerous contact most often occurs in the laboratory, unless extreme care is taken to avoid spillage of mercury. Droplets of mercury falling on a dusty or slightly oily floor separate into smaller particles on impact, and do not coalesce readily because of the dust or oil film which coats them. This results in a greatly increased surface area for volatilization and permits finely divided droplets of mercury to be stirred into the air with dust.

IV. Toxicology

a. General Considerations [5, 6, 7]

Mercury is a highly toxic metal capable of producing serious acute or chronic poisoning. Mercury may enter the body by inhalation, skin contact, or ingestion. Acute mercury poisoning usually results from the ingestion of the more soluble mercurial salts, and is seldom encountered as a result of industrial exposures, although there are a few reports of acute mercury poisoning occurring in industry as a result of the inhalation of high concentrations of mercury. Chronic mercury poisoning or mercurialism commonly results from the inhalation of low concentrations of mercury vapor or extremely fine droplets of mercury in industry.

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[a] Figures refer to bibliography on p. 5.

Mercury is rapidly taken up by the tissues, and can be recovered from the kidneys, liver, spleen, intestinal wall, heart, muscles, and lungs. Mercury is excreted primarily via the kidneys and the large bowel, but traces are found in all body tissues. Following a single dose of mercury, most of the material is eliminated within six days, but traces can be detected for months after the material has been given, indicating delayed excretion. Consequently, there is a cumulative effect of repeated small doses of mercury.

The amount of mercury necessary to produce poisoning has been variously estimated by different investigators. Koelsch and Ilzhofer assert that 0.4 mg to 1.0 mg of mercury daily for one month will produce poisoning, whereas Turner concluded that daily 8-hour exposures to an atmosphere containing as little as 0.00057 mg of mercury per cubic meter of air will result in the absorption of 0.77 mg to 1.26 mg daily and the production of definite evidences of poisoning. The analytical data of Turner are held to be low by other workers, however, who claim that greater amounts of mercury must be inhaled before poisoning is encountered. There is a decided lack of unanimity of opinion on this subject in the literature, and it appears that a "middle of the road" attitude is justified.

In another instance, 16 of 20 laboratory workers developed definite evidence of mercurialism after 5 months of work. Careful cleaning of the floor of this laboratory resulted in the recovery of ½ lb of mercury behind a cupboard.[8] Experiments on dogs [9] indicate that the lowest concentration of vapor in air which will produce toxic effects following 8-hour daily exposures for 40 days was 3.05 mg per cubic meter of air. No ill effects followed similar exposures to 1.89 mg of mercury per cubic meter.[9] In the felt-hat industry, however, 4.5 per cent of workers exposed to 0.2 mg of mercury per cubic meter of air were diagnosed as having chronic mercurialism, whereas 17.1 per cent of workers exposed to higher concentrations were so diagnosed.[10, 11] The effect of prolonged exposure to mercury in the hatters' trade is eloquently described in Lewis Carroll's *Alice in Wonderland*.

b. Acute Effects [12, 13, 14]

Acute mercury poisoning is well known to general medical practitioners because of its frequency following the accidental or suicidal ingestion of mercuric chloride. Acute mercury poisoning resulting from industrial exposure is relatively rare, although some cases of acute mercury poisoning, some of which terminated fatally, have occurred as a result of industrial exposures to mercury vapor.[13, 14] Such cases have resulted from the vaporization of mercury from red-hot surfaces or the exposure to high concentrations of the vapor in confined spaces, such as boilers which have contained mercury. The acute mercury poisoning developing in these cases was characterized by dizziness, abdominal pain, vomiting, and a metallic taste, followed in a few hours to a day or two later by diarrhea, usually bloody in nature. Anxiety, headache, rapid pulse, and muscle cramps frequently developed, and a dry, irritative cough was noted.

The swallowing of a globule of metallic mercury is without serious consequences due to the rapid passage of mercury through the body and the insolubility of metallic mercury in body fluids. Serious kidney damage in such cases is indicated by the presence in the urine of albumen, granular casts, renal epithelial cells, and blood. Death may occur in 6 to 7 days, but most cases recover in 10 to 14 days. There may be sequelae however, characterized by exaggerated reflexes, peripheral-nerve hypersensitivity, tremors of tongue and fingers, a stiff, unnatural gait, pallor, and mental depression.

c. Chronic Effects

Chronic industrial mercurialism is an insidious, slowly developing disease which may be unrecognized for a considerable period. Two general groups of symptoms are encountered. In one, stomatitis, colitis, and nephritis predominate. In the other, tremors, peripheral neuropathies, and psychic changes are encountered.[1] The symptoms are variable, and in general are not prominent, although various combinations of the following are generally found. There may be mild diarrhea alternating with constipation, loss of appetite, and abdominal distress or a sense of fullness. Albumenuria and other kidney findings may be present, but frequently are entirely lacking.[5] There may be changes in the mouth, characterized by inflammation of the gums which become soft and spongy, increased salivation with enlargement of the salivary glands, and a metallic taste in the mouth.[5]

The teeth may be loose, or may be expelled following the development of abscesses.[2] Such changes are generally observed in the more rapidly developing cases, but may be entirely absent in those which develop more slowly.

The more slowly developing cases are more apt to be characterized by nervous-system changes. The commonest symptom in these is a characteristic intention tremor which develops slowly and usually first involves the muscles of the eyelids, tongue, and fingers. It is a typical intention tremor, increasing with effort and lessening with repose and solitude. It disappears during sleep. As it becomes worse, it spreads to the extremities and is accompanied by jerky movements which make walking difficult. The respiratory muscles may become involved, causing great difficulty in breathing. Psychic irritability characterized by timidity, groundless fears, and sudden rages may be present.

Chronic mercury poisoning usually responds well to withdrawal from exposure. Recovery is fairly rapid (usually in a few weeks) in cases with stomatitis or intestinal symptoms, but may be considerably delayed in persons with nervous-system changes. The prognosis is least favorable in those with long-standing tremors and mental changes.

d. Safe Limits

The American Standards Association [15] and most states [16] accept a concentration of mercury in the air of 0.1 mg per cubic meter of air. This figure is based primarily on an extensive survey of conditions in the felt-hat industry conducted by Neal and his associates,[11] in which it was found on the basis of examination of 534 hatters in 5 representative felt-hat factories that no injury to health occurred where the exposure was less than 0.1 mg per cubic meter of air.

V. Treatment

A detailed discussion of the treatment of acute mercury poisoning is beyond the scope of this review, as such cases are extremely rare in industry. However, mention should be made of the recent and excellent work of Leutscher and Longcope, which indicates that BAL (British Anti-Lewisite; 2,3-dimercaptopropanol) is an effective antidote in acute mercury poisoning. It can be given with benefit even many hours after the onset of symptoms, but is more effective if given early in the course of the disease.[17]

Chronic mercury poisoning generally responds well to removal from the hazards. However, workers with neurological or psychic changes respond less rapidly than others, and the prognosis should be guarded. There are no recognized specific measures, and so far there has been no evaluation of BAL in chronic mercurialism. Treatment is, therefore, symptomatic, and should be directed at relieving the symptoms as they are encountered.

VI. Examinations

a. Pre-employment

Workers who are likely to undergo exposure to mercury, such as analytical or research laboratory personnel, should receive a careful pre-employment physical examination, including chest X-ray, urinalysis, and blood count, with particular attention to stippling. Individuals with serious, potentially progressive organic diseases such as tuberculosis or kidney disease should be barred from such employment, as should chronic alcoholics or those in poor physical condition. Most authorities recommend that individuals under 18 years of age be excluded from such employment.[18] Workers with poor teeth should be required to have them repaired prior to such work.

b. Periodic Examinations

Workers undergoing regular exposure to mercury should be checked by the medical department approximately every six months. Particular attention should be paid to the presence of stomatitis, gastrointestinal or neurological symptoms. The frequency and completeness of such examinations may, of course, be modified on the basis of the conditions encountered. Workers with evidences of mercurialism should be withdrawn from such exposure at least temporarily.

VII. Precautionary Measures [4, 19, 20]

The cardinal aim of all safety precautions for the use of mercury is the elimination of mercury vapor from the air. This can be done by the maintenance of good housekeeping, which prevents the spilling or dissemination of metallic mercury on floors, benches, etc., and by the maintenance of the utmost cleanliness and neatness. Flowers of sulfur added to the sweeping compound can reduce contamination from the floor

particles. Evacuation of air which might contain mercury is an adjunct of secondary importance, but one which is necessary in occasional situations. The use of polysulfides to control mercury vapor (Randall's method)[21] may be of value in certain situations.

The following *working rules* will aid in attaining the foregoing standard:

1. Maintenance of strict personal cleanliness.
2. Storage of mercury in closed containers or under water in suitable flasks.
3. Strict attention to the avoidance of spilling of mercury. It should be the responsibility of workers spilling mercury to see that it is cleaned up at once. Flooding spilled mercury with water is an added help. Mercury may be picked up with suction, but the vapors from the pump should not be discharged into the room. An air blast or air hose should never be used to remove mercury from floors or from equipment.
4. All apparatus, benches, and floors should be kept as clean as possible, in order to simplify the recovery of spilled mercury. Floors should be sprinkled and swept wet twice each day.
5. Eating or smoking and handling of food or tobacco by workers in laboratories where mercury is plentiful should be forbidden.

The foregoing rules can be achieved more readily if equipment and laboratories are properly designed and constructed. Wooden benches and floors with cracks should be avoided, as they tend to collect mercury. Work benches should be of enameled steel or of similar smoothness, and free of cracks and crevices. Walls and floors should be of a smooth, even, hard finish, without cracks. It is also desirable to have floors sloped toward a covered sump or catch basin to which mercury can be drained or flushed.

Adequate general ventilation is essential, and local exhaust ventilation should be provided in any situations where excessive contamination by mercury vapor is possible.

The air in laboratories should be sampled frequently in order to insure the maintenance of safe conditions.

Finally, workers who must be exposed to unsafe concentrations of mercury vapor should be equipped with supplied air-type respirators. In situations where the use of an air hose would be awkward, a gas mask equipped with a canister approved for use with mercury vapor should be provided.

There are a variety of acceptable methods for determining the presence and concentration of mercury in air. Mercury vapor in the air may be determined directly by means of the General Electric selenium sulfide detector,[22] or one of the less cumbersome and more rapid photoelectric detectors,[7] which depend on the scattering of the resonance radiation of mercury by mercury vapor. However, mercury dusts are not measured by such apparatus; therefore, they must be determined in other ways. There are a variety of acceptable methods,[7] among the most recent, and apparently most desirable, being one recently reported by Barnes[23] which employs the standard impinger for collection of the samples and a simple colorimetric analysis for mercury. This method determines both mercury vapor and dust; is simple and rapid; and has an accuracy of better than 90 per cent. Mention should also be made of the electrolytic method, in which the contaminated air is passed through a tube chilled by liquid air, liquid nitrogen, or a solid carbon-dioxide–ether mixture. The deposited mercury is then dissolved in chlorine water and determined by electrolytic disposition and micrometric measurement. This method is adaptable to urine samples as well as to air.[24]

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