SALIENT FACTS ABOUT ATMOSPHERIC LEAD AND AIR POLLUTION

by

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Tetraethyllead, tetramethyllead and related lead alkyls, in certain formulations of antiknock compounds, are added to gasoline at oil refineries to improve the performance of the internal combustion engine in which gasoline is used as fuel. These compounds are burned with the gasoline in the engine, and their combustion products are discharged from the engine as finely divided inorganic compounds of lead. Some portion of these inorganic compounds condenses out in the exhaust system, and the remainder escapes into the atmosphere from the tail-pipe. All but minute amounts of the organic lead compounds are burned in the engine, so that the quantities of organic lead which reach the atmosphere are practically negligible.

Despite impressions to the contrary, there is a great deal of information on the concentration of lead compounds in the atmosphere and on their relation to public health. During the period of its use, beginning in 1923, experimentally, tetraethyllead has been one of the most comprehensively studied of industrial products, from the standpoint of the public health. This work has been carried out, for the most part, in the Kettering Laboratory in the College of Medicine of the University of Cincinnati, under the financial sponsorship of the manufacturers and distributors of antiknock compounds in the United States of America, through agreements with the Board of Directors of the University. The results of these investigations have been published in scientific

Second, it is necessary to take into account the presence of lead in the food, water and other beverages consumed by human beings. The quantities of lead taken into the body in this manner greatly exceed the amounts taken in with the air in breathing. While the average of a large number of observations on the human intake of lead in food and drink approximates one-third of a milligram per day, that taken in in the air within the 24-hour period may be as little as one-twentieth of that amount, or as much, perhaps, as one-fourth of it, depending upon where and how one spends the hours of the entire day. (The areas of a city vary, with respect to the lead in the air, and the respiratory volume varies greatly with the size and the activities of the individual.)

When one considers the extent of the absorption of lead into the body, as differentiated from its entry into the alimentary and respiratory tracts, the quantitative relationships are somewhat more significant. Thus, the absorption from the digestive tract is slow and incomplete, somewhat less than 10 per cent of that swallowed, under ordinary conditions, being absorbed. On the other hand, that absorbed from the respiratory tract, under the conditions which exist commonly in the air of cities, may range between 25 per cent and 50 per cent of that which is inhaled. In an ordinary day, the average individual in the general population may absorb approximately 30 micrograms (0.03 mg.) of lead from his digestive tract, and somewhat less than a corresponding quantity of lead (of the probably order of 10 micrograms) from the air. It may be seen, therefore, that the lead in the food and beverages is likely to be more important than that which is in the air, in determining the extent of the absorption of lead from day to day by persons in the general population; prolonged observations on human subjects indicate that under the ordinary conditions of life in Cincinnati, the former

source is considerably more important than the latter. The evidence also indicates clearly that, under present conditions, the output of lead daily from the body of the average person is so nearly equivalent to the total intake daily, that any accumulation of lead which may occur over a long period of years, or a lifetime, is too small to be detected.

In line with the statement above, concerning the quantities of lead which may be inhaled, it appears that the atmosphere of individual American cities may contain, on the average during all seasons, from 1 to 3 micrograms of lead per cubic meter. This range of values contrasts with the concentration of 200 micrograms per cubic meter, which has been accepted in the United States as a satisfactory specification of the safe concentration of lead in the air of industrial establishments. This specification is not applicable to the general atmosphere, because of the intermittency of occupational exposure to lead (approximately 40 hours per week), as opposed to the constancy (in time but not necessarily in severity) of the exposure of the population to the ambient air. Experiments have been underway in the Kettering Laboratory for several years to determine, in precise physiological terms, the upper limit of the safe concentration of lead in the air to which the general population may be exposed.

Additional determinations of the lead content of the atmosphere of several cities, including Los Angeles, have been made, jointly, by the U. S. Public Health Service, city and state health agencies in Philadelphia and California, and the Kettering Laboratory. The results of this joint investigation, which have appeared in Public Health publication No. 999-AP-12, confirm the essential truth of the statements made above, and give them broader geographic application within the United States.

The concentration of lead found from day to day in urban atmosphere ranges upward and downward from the levels cited herein as averages. Occasional

high values have been found and reported. These, in some instances, have assumed an importance far beyond their true significance. Such results may be expected to occur occasionally in any survey, because of the concurrence of unusual factors and also because of the opportunities for error in sampling and analysis. For practical purposes, the prevailing or average conditions of exposure are the significant ones. To be valid and representative of the facts, sampling must be carried out systematically to meet all kinds of conditions over extended periods of time.

This statement is not concerned with the economic impact of restrictions in the use of antiknock compounds in gasoline upon the oil industry and the motoring public. From the standpoint of public health, however, it is important to know that such restrictions would not eliminate all of the lead from the atmosphere, and it may not even eliminate the large proportion of it. Periodic and fairly comprehensive investigations of the lead in the atmosphere in Cincinnati have shown that there has been a significant reduction in the lead content since the late 1940's. This is traceable in part to a reduction in airborne lead contributed by the combustion of coal, and in part to changes in the commercial activities and traffic patterns in Cincinnati during that period. This reduction took place despite the progressive increase in vehicular traffic and in the consumption of gasoline. To the extent that this reduction of lead in the air was achieved by the reduction of the combustion products of coal, it has called attention to the significance of this source. It appears that the amounts of lead in the atmosphere of Cincinnati from the combustion of coal, some years ago, were equivalent, at the least, to those derived from the exhausts of automobiles. This fact alone may introduce a somewhat more balanced perspective into the consideration of this matter in relation to the past as well as the future.

The ultimate criterion of safety, in relation to human exposure to lead from any or all sources, is the freedom of the individual from a rate of intake and absorption which will result in the progressive accumulation of lead in his body over a long period of time. The evidence indicates that, under the present general conditions of exposure, outside of the lead industries, no such accumulation occurs. The additional evidence which is being sought through further experimentation is intended to define the threshold point in the over-all exposure to lead in food, beverages, and air, which will result in a barely demonstrable accumulation of lead in the body. By such means, the margin of safety between present conditions and potentially hazardous conditions can be established, and a standard for the future made available.

Two sets of experiments have been designed, one of which has been completed, in order to obtain the evidence referred to above. These experiments are variants of a general procedure which has been developed in the course of some twenty-five years os systematic investigation of the intake and output of lead by human subjects, under carefully controlled conditions in the Kettering Laboratory.

(1) Briefly, as to the first of these experiments, two healthy men were kept under close observation, under strictly parallel conditions, over the period of many months. After a preliminary period sufficient to include the major climatic (seasonal) changes in Cincinnati (hot, cold and temperate seasons), during which each subject collected, daily, for analysis for lead, all feces and urine, and duplicate samples of all food and beverages consumed, the two subjects were introduced into two parallel respiratory chambers, and subjected, for definite periods of time, to identical (as nearly as possible) conditions of temperature, humidity, rate of flow of air, and quality and concentration of

lead in the air (0.15 mg. Pb, as the sesquioxide, dispersed as minute particles of the mean diameter of 0.05 micron, ranging up to 0.2 micron in diameter). The purpose, here, was to determine the effect of duration of exposure upon the physiological processes involved in the absorption, excretion and retention of lead in the body, so as to be able to appraise the significance of continuous versus intermittent exposure to lead in the air (so as to be able, eventually, to determine the weight of this factor in the differentiation of the effects of occupational from general environmental exposure (in the atmosphere of the community) to airborne lead). Since it was virtually impossible to conduct this experiment continuously with human subjects, reliance was put in the experimental device of comparing the effects of a series of shorter periods of exposure and of extrapolating from these data to the end-point in time. Thus the men were subjected to exposure, to the conditions described, for 3 hours per day on every other day for several months, then to 6 hours, 9 hours and 12 hours per day on every other day for corresponding periods of several months. By this means several points on a curve were established, and the curve extended to 24 hours per day on every day.

The results of this experiment were extremely gratifying, in that the two subjects reacted nearly identically, and a smoothly graduated increase in the absorption and retention of lead (as shown most effectively by the concentration of lead in the blood), paved the way for a straight-line extrapolation of the findings to the level of continuous exposure. It is of interest to reckon with the evidence, derived from these observations, that a dangerous level of lead absorption would have been arrived at in less than 2 years by the two subjects, under the conditions of continuous exposure to a concentration of lead in the air that has been found to be safe, indefinitely, under occupational conditions

involving approximately 40 hours of exposure per week. The strikingly different effects of continuous versus intermittent exposure to air-borne lead, may be stated somewhat too precisely, but otherwise realistically, as the outcome of this experiment, as follows: Under comparable environmental conditions, with respect to the specific compound of lead and the dispersion of particles in the air, a man can work indefinitely (presumably for a working lifetime) for 40 hours per week in an atmosphere containing 0.15 mg. of lead per cubic meter; whereas the same man, attempting to live continuously in such an atmosphere, will have absorbed an amount of lead sufficient to induce lead intoxication in somewhat more than 1 year.

(2) The next experiment, now in progress, was intended to determine the highest concentration of lead in the atmosphere which, when breathed continuously, would fall just short of inducing a measurable, progressive accumulation of lead in the body of the normal healthy human subject. For practical purposes, since a totally negative result would provide no numerical representation of the quality of air in this respect, the experiment was designed to detect the least concentration capable of inducing a barely detectable effect upon the absorption, excretion and retention of lead. Again, two experimental subjects, after the appropriate preliminary observations, were introduced into parallel respiratory chambers in which they were subjected to the inhalation of air containing 10 micrograms of lead (as the same compound in the same state of subdivision as that indicated above), per cubic meter of air. (This concentration was selected as the starting point, to be increased step-wise as might prove to be necessary, in the belief that no positive result would be induced.) The subjects were to spend a period of several months in a regiment involving exposure for 3 hours per day on alternate days, after which, over corresponding periods of months, they were

to be subjected, successively, to the same conditions for 6, 9 and 12 hours, respectively, on every other day.

This experiment after somewhat more than two years of gradually increasing periods of exposure is now at the stage of $12\frac{1}{4}$ hours per day on six days of each week. There has been no increase in the rate of excretion of lead in the urine or in the concentration of lead in the blood of the subjects. With the completion of this phase of the experiment in February of 1966, the concentration of lead in the air of the chambers will be increased and the cycle of increasing hours of exposure will be resumed. The experiment will be carried to its intended and logical conclusion.

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