# INDUSTRIAL HEALTH ASPECTS OF LEAD COMPOUNDS

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## Introduction

Many years ago and up until the early twenties in this country, the use of lead was extra hazardous in industry and poisonings were the rule. They were expected. Now such is no longer the case. I am proud to be a member of the profession which had a great deal to do with the reversal of this situation. But we Industrial Hygienists were not alone in our efforts at reversing the lead poisoning trend, for this job was a good example of cooperation by industrial physicians, toxicologists and hygienists. Perhaps the key effort was that of toxicology, and as we proceed further we will understand better the reason for saying so.

Due to time limits, it will not, of course, be possible to cover in a complete manner all of the various lead-using industries and the various control methods required to prevent undue human exposure. Therefore, we will discuss this morning some of our knowledge of the effect of lead on the human system with especial reference to industrial exposure and then proceed to a philosophy of control for human exposure in industry which should apply generally.

## Toxicology

Because lead exists everywhere and in all biological organisms of which we have knowledge, its control in the human system consists first in the recognition in quantitative manner of what is normal or usual and, following this, the measurement quantitatively of the additional body burden imposed by the particular exposure. Generally, toxicologists work with small experimental animals such as rats, guinea pigs and rabbits. This is most necessary because they must over-expose in order to determine toxic ranges from harmless to harmful. Ideally, of course, toxicologists should be able to work with human beings since the effect of the material under investigation always must be related to a human and it is well known that no experimental animal approximates sufficiently the human reaction. Lead has, of course, been subjected to animal experimentation many times in the past but, in addition to this work on animals, I want to mention to you some of the unique human exposure experiments which have been carried on in this country since about 1927 at the Kettering Laboratory in Cincinnati. Interestingly enough, the main reason for the initiation of these experiments was to investigate in every way the use of tetraethyl lead as a gasoline additive and its effect on the health of workers in the industry and on the health of the general population. As far as a toxic investigation is concerned then, lead has been the subject of an ideal study continuously since 1927. We may say at this point that no other material in use in the modern world has been more completely and more thoroughly investigated from the standpoint of human health.

Briefly, the Kettering experiments were first involved with the ingestion hazard and were carried out by means of controlled feeding daily of known amounts of lead in food and beverages to human subjects. These experiments were carried on continuously for some eight or ten years until a vast fund of quantitative knowledge was accumulated. Then, the more complicated inhalation experiments were started and these are still being carried on. Since these researches as well as those of every other investigator in the field have shown that, at least on the industrial scene, the most important hazard potential to be from the inhalation of finely divided particles, we will pass over a discussion of the ingestion experiments. Suffice it to say, however, that the ingestion experiments did provide a most important base-line for the understanding of the metabolism and fate of lead in the human body.

Knowing that all humans contain normal amounts of lead in their bodies, it becomes necessary to ascertain that normal amount before any exposure experiments worthy of the name of Science can be initiated. In order to make this determination, each experimental subject is followed for an average of one year before the experiment starts. He is followed in this manner. All of his food is analyzed for lead. All of his beverage consumption is analyzed for lead. The air that he breathes during his eight-hour exposure period is analyzed for lead. All of his bodily excretions are analyzed for lead. As the experimental subject carries on his work at the laboratory location in a small room equipped as an office, which room serves as the exposure chamber, it is a relatively simple matter to determine the amount of lead he inhales during his eight-hour working day. What happens during the other sixteen hours of the day can only be approximated, but has been checked by testing the air in and about the city of Cincinnati, where all these experiments have taken place. Think, if you will, of the magnitude of this undertaking. During a subject's eight hours in the laboratory, it is a relatively simple matter for the investigators to analyze all his foods and beverages, plus all of his bodily excreta. However, during the sixteen hours that he is away from the job there are a great many complications, but a satisfactory procedure has been established. If the subject should eat a restaurant meal, he orders a duplicate. The duplicate is placed in a lead-free container and brought back to the laboratory. If the subject wants a cup of coffee or a coke, he orders two coffees or two cokes as the case may be, and brings one back to the laboratory for analysis. Similarly, all of his excreta are saved and brought back to the laboratory for analysis. And, as I said previously, this goes on for a year in each case before the experimental exposure starts. At the end of this year the laboratory has a thoroughly-documented data sheet covering just about everything that can be known about this individual and his lead body burden. Of course, clinical and biochemical analyses are continuous all during this pre-exposure period and during the exposure period as well; for instance, a blood sample is taken once a week, at least, and other examinations including heart, lungs, and so on, are continuously made. I might mention here that the subject is followed for at least this long, and usually longer, at the termination of the experiments to make certain that nothing is missed which may be of significance.

The thoroughness, accuracy, and precision of these before-described experiments which, I believe, without precedent in the world of Science, have led over the past thirty years to a tremendous fund of knowledge about lead and its effects in the human system--knowledge which in every case is quantitative and significant. From these experiments and their data gathered in the Kettering Laboratory and elsewhere, we have a picture of what happens to lead when it is taken into the human body. We know, for instance, that the average adult body contains a total of at least 80 mg. of lead. We know that the average adult ingests about 0.3 mg. of lead a day from his food and beverages, 90% of which is eliminated via the fecal tract. We know the normal range of variation of lead concentration in the blood and the urine. We know how much lead it takes via the inhalation route to tip this balance over into an excessive absorption or intoxication range. The picture then is of a human body which contains a certain amount of lead distributed throughout its organs and tissues in a fairly well blue-printed manner and which body takes in a certain amount of lead in a unit period of time and eliminates a certain amount of lead in a unit of time. From the results of these experiments, and others like them, certain standards for lead exposure have been set. For instance, there is a drinking water standard that applies throughout the United States. There is an eight-hour per day industrial exposure standard for lead in the air of workrooms. All of these standards are based on logic and experience and are susceptible to adjustment either up or down, as facts may dictate.

May I point out to you at this time that, although my subject is lead, most of what I am saying today, as far as body burden and known amounts are concerned, will apply to all other metals and many, many other substances and materials. In other words, lead is not alone in being found as a normal constituent of the human body.

Thus we may see the tremendous help that the Science of Toxicology gives those of us who are concerned with prevention and control measures. We see that prevention measures designed for a 100% elimination of lead, or anything else for that matter, will be frustrated at the start and impossible of achievement. Adequate employee protection requires that standards and goals be set and that recognition of the facts in a particular situation is absolutely necessary in order to control whatever the exposure may be. As we have been discussing, the situation with regard to lead is particularly fortunate in that we have more valid information on which to act than for any other material. Knowing then what our judgment criteria will be, we may then examine the situation that we wish to control, keeping in mind always that the magnitude of the hazard is in almost direct proportion to the amount of fine respirable dust or fume that we allow to contaminate the area. Ventilation, respirators, wetting down of surfaces and fine powders, complete enclosure of processes and so forth, are among the engineering tools at our disposal for control of the exposure.

Since, as we have already pointed out, we can never achieve absolute or 100% control or elimination of any toxic or foreign material, we must have medical supervision for our employees. The industrial physician performs several functions which are not necessary to mention in our present discussion. However, of prime importance to us and to the physician is his function in the prevention of excess absorption of the toxic material, in this case lead. He will usually need measures of biological fluids, notably the blood and the urine. Such measures should be made before any job exposure and at routine intervals during the exposure. Such quantitative measurements are not, in themselves, diagnostic of anything. They are merely aids to assist the physician in the periodic clinical evaluation of the exposed employee. With adequate engineering control measures, clinical examination of exposed employees will be negative. When these examinations reveal otherwise, there has been a failure in our control system. Today in the lead-using industries, there aren't many failures nor should there be.

Control Measures

We have analyzed what seem to us the various characteristics which appear when increased absorption and poisonings occur in industry. From this analysis we may say that there appear to be four such characteristics which are present and which operate somewhat as a chain of events, which when present add up to the undesirable effect of increased absorption in the human system, and the unfavorable upset of balance which we had previously mentioned in the human system. These four characteristics, it seems to me, represent a chain which may be broken by the application of proper control measures, as we will outline presently, any one of which will operate to reduce the effect and eliminate unnecessary absorption and metal poisonings. You will note that I am speaking now in general about all metals because the same principles that apply to lead protection also apply to increased absorption and protection against poisonings from exposure to other metals.

Let us list these four characteristics which we have found to be in operation in every industrial situation where poisonings have occurred.

(1) There is exposure to enough of the metal.

(2) There is exposure to the right kind or the right form of the metal.

(3) There is inadequate protection for the man.

(4) There is a characteristic that the individual is in a physiological state of readiness to suffer a toxic effect.

The first characteristic, that there must be an exposure, or exposures, to enough of the metal, it seems, is perfectly obvious and need hardly be mentioned. And yet, many times in our experience physicians, managers and others in industry will say that the man has lead poisoning because he is working with a lead compound. Since in modern civilized life and in modern industry

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everyone of us every day comes in contact not only with lead and lead compounds but with iron, copper, aluminum, manganese, and so forth, all of which have caused poisonings in the human system, it is rather silly to allege that a mere exposure to a metal results, or has resulted, in an untoward effect. If we remember from our discussion of the Kettering experiments that the human system contains a certain amount of lead in a sort of dynamic equilibrium and that daily intake is balanced by daily excretion, and that complete elimination of exposure to lead, or any other metal for that matter, is an engineering and economic impossibility, we will realize that our concern in control of poisonings must lead us to more precise analysis of situations than is represented by the mere identification of lead (or other metal) in the immediate environment.

The second characteristic of an industrial poisoning situation, that there must be exposure to the right kind or right form of the metal, is again really quite obvious. But so many times the obvious is ignored or forgotten when pressures are brought to bear and anxiety enters into the situation. For instance, in the finishing of automobile bodies, the lead soldered areas are smoothed over to eliminate surface imperfections before the painting operation. When such filing and sanding is performed manually, that is without power tools, large amounts of lead are used and introduced into the environment but in a form in which the particulate size is so large that it cannot be inhaled. There is, therefore, little or no exposure to lead in these situations. We could cite many other examples, such as the well known fact that galena ore, which is lead sulfide, appears to enter into the human system with difficulty and, consequently poisonings from exposure to this material do not occur.

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The third characteristic, that protection for the man is always inadequate in a poisoning situation, is another obvious characteristic which may be forgotten in practice. I give you the example of a well-designed ventilation system removing hazardous amounts of material from the air before the employee ever has a chance to inhale it. The exposure potentials exist certainly but the man is protected and may work without ill effects even while surrounded by high concentrations of material. The employee may be provided with respiratory protective devices for exposures such as metallizing. Or he may work in an air-conditioned crane cab in a foundry, as another example. In all of these situations he is surrounded by hazardous amounts of hazardous kinds of material and yet he suffers no ill effects.

The fourth characteristic is one that I have labeled a physiological state of readiness to accept and react adversely to the metal. This is a characteristic which I do not like to introduce because I can't explain it and because it is difficult to control. I think we have all seen examples, however, where one or two men out of a workforce of a dozen will come down with a case of poisoning in a work situation where all factors are common throughout the area. There are probably good explanations for such occurrences but they vary with the situation and the individual. I suppose it would be ideal if all of us reacted in exactly the same manner to our environment so that a single standard would apply and that environmental controls could be applied as in an exact science. Philosophically speaking, this might make for a certain monotony in life. However, as I said previously, it is a rare industrial situation in which everyone reacts in the same manner and to the same extent when a toxic insult strikes.

I have found that the use of the above four characteristics to devise control measures that will aid in the prevention of excess absorption of metals is a handy mental concept and really helps to clarify a situation which may be confusing at its first onset. For instance, we find that in most adverse industrial situations where poisonings and excessive absorptions in men exist, all four of the above characteristics are operating. By removing or controlling any one of the above, the effect is that of breaking the toxic chain and poisoning no longer results. Engineering of ventilation systems, process changes, introduction of new or substitute compounds or materials, improved housekeeping, better materials handling techniques, systematically-controlled provisions for personal hygiene, and enlisting the cooperation of employees by frank explanation of the hazards and control means proposed are among the most important methods to be used.

We have attempted to outline for you present day thinking on the toxicology of lead and the way this thinking influences those of us concerned with prevention and hazard control functions in industry. And I believe we have shown the necessity for developing in industrial toxicology quantitative, or measured relationships between humans and their working environment, and that such quantitative relationships have been thoroughly established for lead exposures. This, together with the fact that most of the adverse lead exposures in industry today are the result of airborne material of respirable sizes, has led us to an analysis of the four industrial characteristics that we must address our control measures at in order to succeed. The amount and kind of exposure, the protection of and physiological state of the man are the important factors, control of which can complete our equation of safety.