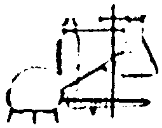
History: fact and fallacy



From the earliest gropings to understand the nature of lead and its effects on the human body, the history of lead in relation to industry provides a fascinating account of efforts to arrive at a dual goal of developing:

- Engineering controls within the plant environment, and
- Physiological balance measurements for an effective preventive program.

Our present knowledge on both levels did not develop overnight. The ancients wrestled with the problem. A primitive solution, suggested by Plinius Secundus, who lived from 23-70 A.D., called for a protective mask. Made from a bladder, the mask was placed over the face to prevent the inhalation of dust and fumes from lead as well as other materials.

Ben Franklin, widely known for his varied interests, got in on the subject with the "theory" that fumes from heated type, placed on stoves to dry after cleaning, were causing printers to develop loss of movement in their fingers over a long period of time. Pottery-making and glass-making were other trades examined by the colonists, looking for the explanation of symptoms they called "dry gripes" - a catch all term used for all types of abdominal pains unaccompanied by fever or diarrhea.

As knowledge progressed, other pioneers tackled the problem. It wasn't until the early 1800's that scientists and physicians were able to separate some of the prevailing fact from fallacy when they began to examine the ways lead could enter the body - by inhalation, ingestion, or skin absorption - and to study which was the chief mode of entry.

Painters were the first industrial group to be studied with any thoroughness in the modern era. Whether inhalation or ingestion was the chief cause of "Painter's Palsy" or of "Painter's Colic," or whether it was attributable to other causes, was examined and discussed by doctors and scientists in the early part of the nineteenth century.

It was not until the mid 1800's that physiological tests were introduced. In 1840, the Burtonian Line, or "Blue Line," was first described by Dr. Burton, who defined a blue line on the gums as symptomatic. Divergence of opinion on this test arose, as this "blue line" was shown not always to be a "lead line."

The next diagnostic aid to be introduced was that of granular basophilia, or "stippling," the condition in which the red cells are filled with dark, fine granules. Though helpful in diagnosis, it was noted that stippling also occurred in such diseases as malaria, carcinoma, tuberculosis, dysentery, leukemia, cachectic states, septic processes, secondary anemia, as well as poisoning from certain drugs.

Even before the advent of "stippling" as a diagnostic tool, studies of the presence of lead in the urine were underway. The determination of the porphyrin content of urine in relation to lead stems from work conducted about 1894.

After the turn of the century, the industrial hygienist began to emerge. As his work evolved plant design parameters for the protection of employees in industry, the environmental approach caught up with the physiological approach. The work of Legge and Goadby with British industry established the first standards to apply to concentrations of lead in the air.

By 1912, when their studies were published, efforts were going forward to develop methods of determining the amount of lead in blood and urine to estimate lead absorption. A number of tests were evolved, but it was not until the mid 1930's that the major breakthrough occurred.

It was at that time that the dithizone test was developed, providing a highly sensitive and practical means of determining lead levels in blood and urine. A discussion of standards for these levels, achieved through subsequent scientific study, is included in this bulletin.

If development of physiological tests moved haltingly, it can only be said that therapeutic methods moved erratically. At the time "stippling" was gaining currency, one of the very physicians who cast doubt on its efficacy, Sir Thomas Oliver, was suggesting one of the more dramatic therapeutic measures to come along: a double electrical bath treatment for "removing lead from the body." Each worker, immersed daily between two electrodes in an electrolytic bath, was presumably de-leaded by the treatment. Soon, it became recognized that the treatment contributed more to the worker's sense of wellbeing and relaxation than it did to his physical health.

Even so, such "treatment" abounded, including:

- Epsom salts doses for each worker,
- A one-gram calcium sulfide tablet each day,
- Daily quotients of lemonade with sodium citrate,
- A "weak solution" of sulphuric acid, still being suggested as a lemonade as recently as 1963,
- The daily ration of milk, still administered to the present day in a number of plants.

Industrial hygienists and physicians have made great strides in the evaluation and proper application of therapeutic techniques to plant situations. Where these methods have not contributed to a preventive program, they have, largely, been discarded.

Synthetic chelating agents, for example, have been used therapeutically in industrial health programs. The calcium disodium salt of ethylene diamine tetra-acetic acid (Ca EDTA), introduced in 1952, has been successfully used as a medical treatment. Penicillamine, orally administered, is a more recent treatment. But such medications are not recommended as a routine prophylactic measure in a preventive program. Reliance on such prophylaxis leads to a tendency to ignore the engineering controls essential to a good preventive program. Furthermore, Ca EDTA should not be administered except under the direction of a physician.

We have outlined some of the past treatments, the fumbling efforts, the great strides forward that have led to present clinical knowledge and industrial safeguards.

Hand in hand with the development of clinical information and tests have been the efforts of the industrial hygienist in providing engineering controls of the work environment.

The industrial hygienist keeps two factors constantly under consideration: the amount of lead in the air and the amount of lead in the body fluids.

The purpose of what follows is to outline some of the information that the industrial hygienist has available — from the accumulated experience of the past to the widening knowledge gained from day to day in each industrial plant.

Achieving a Balance

Lead is a normal constituent of human tissue from birth through life. Human exposure experiments have shown that there is constant intake and elimination and that the body does achieve and maintain a balance, or dynamic equilibrium, between intake and elimination. The amount of lead in the body is a function of this balance, and so blood and urine lead determinations are used to provide a picture of this balance for each individual and to measure absorption, transport and excretion.

The body's "balance sheet" can be represented in this way:

- The amount of lead in the body remains low when elimination of lead is in balance with intake.
- The amount of lead in the body increases when intake of lead exceeds the amount that is eliminated, and
- A natural form of de-leading occurs when lead intake is low and elimination of lead occurs normally.

With this picture of the physiological balance in mind, let us consider the two-pronged attack used today to control lead exposure:

1. Measuring and controlling the amount of lead in the plant environment, with airborne lead determinations and the providing of engineering controls, and

2. Measuring the physiological lead balance in the employee, through blood lead or urine lead determinations.

These two approaches give us effective means of determining the potential exposure within a plant and the actual exposure of an individual. Action can then be taken to reduce any excessive exposures.

As stated earlier, diagnostic tests and treatments are not stressed in this booklet. If intoxication does occur, it is a result of failure of the primary control measures. Tests should be directed toward evaluating the degree of absorption of lead, since we know that intoxication will not occur unless absorption becomes excessive.

For practical industrial programs, we do not recommend the use of diagnostic criteria such as basophilic stippling, urinary coproporphyria excretion, and delta-aminolevulinic acid excretion—since such criteria are intended as measurements of the *effect* of lead on the body. We wish to know, and must know, the degree of *absorption of lead*, and must have measurements sensitive and accurate enough to tell us this degree of absorption so we may take action long before there is an effect on the body. In other words, by measuring the degree of absorption of lead among exposed employees we can not only alert the individual employee as to the status of his own situation, but we learn in the best way whether or not our engineering control measures are satisfactory.

In a sound medical and engineering program, it is important to balance these two factors:

- *The lead level in the body.* The normal balance of lead in the human body must be maintained. An increase in the lead level in the body is not of itself dangerous or a cause of illness. Maintaining the balance in terms of each individual is vital.
- *The degree of lead in the plant ambient environment.* Proper engineering controls provide the other side of the balance scale. These plant controls, combined with measurement of lead levels in the body, can achieve an effective preventive program.

Thus it can be seen that the prime concern of the industrial hygienist is not the therapeutic and diagnostic work of the physician, but the balancing of physiological and environmental factors in a preventive program.

How these two objectives can be achieved in the work of the industrial hygienist is examined in what follows.

Control of Industrial Exposure

Types of Exposure to Lead in Industry

Inorganic lead enters the body primarily through the respiratory tract, by the inhalation of fumes, dust or mist.

A secondary, but not as significant, means is entry through the gastroenteric tract. This occurs by the swallowing of lead particles trapped in the upper respiratory tract or introduced into the mouth on food, tobacco, fingers and other objects.

Inorganic lead compounds are not absorbed through the skin. Many of the *organic lead* compounds, however, are absorbed through the intact skin.

With inhalation ranking highest in order of importance, with inorganic lead, engineering control of airborne particulates is important for the widest number of industries and processes.

Molten Lead

Many processes using lead require the metal to be melted. Whether the potential hazard is one of fumes or dust is a variable of the temperatures at which the lead is handled in molten form.

Molten lead does not produce significant quantities of fume below 900°F, but lead oxide formed on the surface may become airborne if the surface is disturbed. When lead is poured, agitated or skimmed, oxide formation is increased.

Finely Divided Lead Compounds

Another cause of exposure to airborne particulates is the bulk handling of lead compounds. It is important here to control the emission into the atmosphere of lead in finely divided form.

Lead compound particles may also be released where paints, enamels and glazes are applied by spray techniques. In such industries, engineering control measures similar to those provided for containment of dust and fumes are used.

Permissible Levels of Occupational Exposure

The industrial hygienist has long concerned himself with what precisely constitutes a safe level of exposure to lead in the plant environment. Continuing studies in industry, correlated with controlled exposure research with human subjects, provide the basis for the widely accepted permissible levels in industry today.

The present standard for industrial exposure to lead in air is 0.2 mg of lead per cubic meter of air measured over an eight-hour day. This standard states that, when the air of workrooms contains regularly not more than 0.2 mg of inorganic lead per cubic meter of air, as measured by prescribed methods, cases of lead intoxication will not occur.

Lead Levels in Human Beings

It is only in combination with determination of blood and or urine lead levels in exposed persons that the environmental determinations are meaningful. After the early gropings and recent explorations, two methods of establishing the approximate level of absorption of lead into the body are found most useful:

- Measurements of concentration of lead in the whole blood and.
- Determination of the concentration of lead in the urine.

Blood lead determinations: In a group of plants employing thousands of men working with lead, where periodic blood lead analyses have been used in conjunction with adequate engineering controls, no cases of lead intoxication have been encountered. Any individual whose lead level in the blood is about 80 micrograms per 100 grams of whole blood, while not necessarily ill in any way, is shown to be running a greater risk of developing lead intoxication without warning than those having lower blood lead concentrations. An employee showing this level should not incur further occupational exposure to lead until the concentration of lead in his blood has diminished significantly.

Urine analyses: There are more variables associated with the concentration of lead in the urine than in the blood. There are several reasons why this should be so. The concentration of lead in the urine varies with liquid intake and rather quickly with exposure to lead, whether it be lead in food and beverages, or lead in the atmosphere.

These facts should be kept in mind when using lead in urine measurements for industrial exposure controls. The urine spot sample, of 100-200 ml, will vary considerably in the amount of lead it contains depending on the above-mentioned factors. For instance, the time of day at which the sample is collected influences the amount of lead the sample contains, since the usual exposure in an industrial situation varies considerably during the day, and the urine lead concentration is varying in dynamic equilibrium with the intake of lead. Another difficulty that may attend the use of urine lead samples as measurements of human absorption is the fact that contamination of the sample during collection can and does occur for obvious reasons. All men whose urine is to be sampled are obviously working with lead and will have some lead on hands and clothing.

Mention should be made here of the fact that measurement of lead concentrations in the urine is the only practical measurement when the exposure is to organolead compounds. It has been found that blood lead values change very little following exposure to such material.

It is important that blood and urine determinations be conducted by competent laboratories skilled in this work. A laboratory must be equipped to do microchemical analyses of the utmost sophistication. To cite one example of the importance of the use of a fully equipped and qualified laboratory. Blood samples taken from a normal individual may contain a total amount of lead of one microgram or less. The usual laboratory not proficient in micro-chemical measurement techniques cannot provide analyses for tests as precise as this.

For a complete discussion of the subject of lead in the blood and urine of industrial employees, see Kehoe, Robert A.: *Industrial lead poisoning*, in Patty, F.A., ed.: Industrial Hygiene and Toxicology, 2nd rev. ed., New York, Interscience Publishers, Inc., 1963, vol. II, pp. 941-985.*

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Some Practical Suggestions

Control of exposure to toxic materials in industry is primarily an engineering and administrative problem. It involves dust control, ventilation, plant layout, good housekeeping, the education of personnel in hygienic procedures and a sound medical program. As in other industries, the following steps have helped minimize hazard:

1. Exposure to toxic materials should not be distributed throughout a plant. The application of this principle has a bearing upon the movement of materials through a plant, the arrangement of equipment within it, and the manner of employing ventilating equipment (whether local or general, or both). These, along with other considerations, determine the layout of the plant, its structural characteristics and, thereby, to a considerable extent, its costs.

2. The equipment should be arranged with reference to the hazards and the means of their control, as well as to convenience and speed in production. For example, ventilation can rarely be introduced with completely satisfactory results as an afterthought. There must be space for fans and ducts and for the heating or cooling equipment that may be required to temper the air.

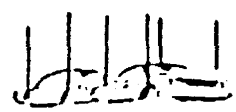
3. Three points merit specific mention in connection with dusty processes in-

volving particulate lead and its compounds: (1) the necessity for the use of carefully designed local exhaust systems to remove fume or dust at points of origin; (2) the need to exercise great care to prevent the reintroduction of contaminated air into workrooms; and (3) the desirability of filtering exhausted dust and fume where necessary so as not to contribute to the pollution of the atmosphere in the neighborhood. The importance of these points will be appreciated only by those who have had broad experience, or by those who, lacking experience, have undertaken to solve these practical problems by methods of trial and error. It is of considerable importance also to so design the ventilation system and the ventilated areas as to insure satisfactory results independently of weather conditions and the personal predilections of employees.

4. The construction and arrangement of the plant must be such as to promote cleanliness and good housekeeping. Floors, window ledges, walls, and working space in general must be designed with specific reference to the materials to be used and the methods of housekeeping that will be employed. For example, floors that are to be hosed down must have unobstructed surfaces and adequate drainage and must not be slippery when wet. Similar purposes may be served by metal grills over-laying a secondary floor equipped with adequate drains. Areas and equipment that are to be cleaned by vacuum must be smooth, regular, and free of all unnecessary obstructions and sharp angles.

5. Facilities for medical services must be designed to fit the medical program that is contemplated, and not on what remains of space and location after other requirements have been satisfied.

6. Sanitary equipment such as toilets, washrooms, locker rooms and lunchrooms, as well as a satisfactory supply of drinking water, should be so planned as to encourage their use. Convenience, comfort, and adequacy in relation to the number of employees are first considerations. In some industries, management requires certain groups of employees to change clothing completely when going to work, and change and bathe at the end of the day's work. Therefore, double lockers for the two sets of clothing, and good bathing facilities are provided. Employees must not eat in certain workrooms; consequently, a clean and comfortable lunchroom must be provided. Good washroom facilities are required to enable the men to cleanse themselves properly before entering the lunchroom. All of these rooms and spaces must be located or otherwise designed so as to prevent their contamination with dust-laden or fume-laden air, and to facilitate frequent and thorough cleaning. Many of these requirements are standard sanitary practices and are often covered by local regulations for industrial plants.



Safeguards: A Case History

Industry has shown dramatic results in engineering control in the use of lead. This is exemplified by the safeguards applied to the use of high-lead solder in the manufacture of automobile bodies.

Until certain practices and safeguards were instituted, the grinding of solder on automobile bodies was an extremely hazardous occupation. Although the grinding of solder is a specialized use of lead, the steps taken to control the dust from this type of operation present a clear picture of what can be done to make operations hazard-free.

Here is what was done to alter the situation:

Stations for torch soldering (involving the use of gas-fired torch and solder) were equipped with overhead exhaust canopies capable of exhausting 100 cubic feet per minute per square foot of open face area. Soldering pots with a capacity of 500 lbs. were equipped with complete hood enclosures, having a capacity to exhaust 150 cubic feet per minute of open face area. Thermostatically regulated heat controls were added to maintain a solder temperature below 650°F.

Mechanical lead grinding operations were isolated in ventilated booths, and employees were furnished with air-line respirators and protective outer clothing.

Strict maintenance procedures for cleaning the physical facilities were instituted and enforced, as well as procedures for inspection of ventilation and other safety equipment. Laundering facilities were provided to clean protective clothing and air-line respirators.

Due to careful study of the problem and proper controls – there are no cases of lead intoxication in this industry today.

Other industries have achieved equally impressive records. The industrial hygienist has used the tools of research and common sense, instituting safeguards that are now common practice in most lead-using plants.

The vast majority of processes involving the use of lead do not require more than the usual controls associated with good industrial hygiene practice. The precautions to be taken in those lead-using manufacturing processes requiring more than routine hygiene procedures can be summed up as follows:

- Obtain assistance from an industrial hygienist.
- Design facilities to afford maximum health and safety protection.
- Provide adequate ventilation and personal safety equipment.
- Enlist the services of a physician, either full-time or part-time to examine all new employees who are to be working with lead and to make periodic examinations as required of exposed employees.
- Set up safe operating procedures and instruct all employees about their use.
- Inspect facilities frequently, to insure that proper procedures are being followed.
- Contact the Health and Safety Director, Lead Industries Association, if you have any questions regarding the use of lead, its toxicity, or proper procedures to be followed.

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