Historical Perspective to a Current Controversy on the Clinical Spectrum of Plumbism

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Concepts of health risk associated with lead usage have undergone profound change. In the past observations of the relationship between lead usage and lead poisoning were severely limited by lack of knowledge and the relatively small quantity of the metal used. The benefits of lead usage, when contrasted with the risk incurred, outweighed the known hazards.

Industrial growth contributed to the increased interest in lead poisoning. A significant increase of workers at risk generated new interest in an old disease. A concept of control developed based upon the principle of a dose-response relationship. The old idea of benefit versus risk remained because technological society needed lead but agreed that by controlling the factory environment lead could be used safely. The criteria for injury remained clinical plumbism.

Growth and change in lead utilization, once again, brought lead hazard to the forefront. New applications distributed lead throughout the environment exposing both workers and the general population. A segment of the scientific community now suggests that the old criteria to judge risk, clinical symptoms of plumbism, are inadequate.

Lead, essential to modern technology, has long been a critical raw material. In the past the benefits of lead usage, when contrasted to the associated risks, outweighed the known hazards. The growth of technology and its by product, an urban industrial society, created an ever increasing demand for lead, and resulted in an inordinate number of occupational exposures to lead in industry. The dangers to health associated with continued exposure to certain forms of lead cover an entire spectrum of symptoms, with the most advanced form referred to as plumbism. In the twentieth century the efforts of workers in the field of industrial health, a changed social climate, and new legislation made the lead industries relatively safe for workers. The injuries to health caused by lead poisoning were considered technologically controllable, and the cost of control was accepted to ensure the continued availability of an essential industrial raw material.

At early stages of scientific and technological growth, which involve the use of needed materials, we often accept the chance of jeopardy to health incurred by utilization of hazardous materials. In many cases, the perils are unknown. As technology becomes more refined, we become aware of more subtle hazards; and, as social philosophy changes, our attitudes toward risks also become more humane. This new awareness of danger and the concomitant change in social philosophy may cause a re-evaluation of the continued utilization of the material in terms of benefit versus risk.

Because of the growth of science and technology, the concept of health risk associated with lead usage has changed. It is no longer confined to severe, acute, or chronic lead poisoning of industrial workers. Our sophisticated technological society has evolved a new set of criteria to judge risk; they include contamination of the total environment. A corollary of scientific and technological progress, the ability to make more accurate and sensitive measurements, has focused attention on small differences in trace quantities of lead in biological systems and in our environment.

The purpose of this paper is to provide historical perspective for the current controversy related to the definition of lead poisoning by showing the relationship between increased lead usage, increased medical understanding of lead hazard and the disease of plumbism, increasing ability to make more accurate measurements, and changing social attitudes toward the disease of lead poisoning itself. By examining the changing attitudes toward the assumption of risk in the use of lead I hope that the dialogue between the two schools of thought on health effects of lead usage will be clarified. Because lead is but one of a number of toxic materials used in industry its story may give some insight into other problems associated with needed but toxic materials used in industry. My purpose is also to reveal the complexity of evaluating the use of such materials.[1]

Lead (Pb), a bluish-gray metallic element with a high degree of plasticity, is widely distributed throughout the world. The principal lead ore is galena (PbS); other common ores are lead cerussite ($PbCO_3$) and anglesite ($PbSO_4$). Since ancient times man has used

[1]Lead is an example of materials essential to industrial society which possess highly toxic properties. Other materials on which recent attention has been focused include mercury and asbestos.

lead for making pipe, paint pigments, and ceramics. Industrial growth resulted in the utilization of lead in literally thousands of products in our society. Today (Hunter; 1957: 218) "because of its plasticity and softness, lead can be rolled into sheet and foil. It can be made into rods, pipes and tube containers. Lead is used in building construction for roofing, cornices, tank linings, electrical conduit, water pipes and sewer pipes. It is used for yacht keels, plumb-bobs and sinkers in diving suits. Antimonial lead is a major type metal. Lead-antimony alloys are used for accumulator plates, cable coverings, ornamental castings, and the filling of bullets for small arms ammunition. Soft solder, used for soldering tin plate and lead pipes, is an alloy of lead. Lead base alloys are used in engineering to make bearing metals."

"Lead is the basic ingredient in the solder that binds together our electronic miracles and it is the sheath that protects our intercontinental communications systems. It is the barrier that confines dangerous x-rays and atomic radiation, i.e. 'shielding material'. It is sound proofing for buildings and ships and jet planes. It is the major component in the batteries that start our cars and it is the gasoline that runs our cars" (Lead Industries Association, 1968:2).

New uses have been found for lead and old ones discarded, but the danger of disease stemming from lead's toxic properties has persisted. Moderns refer to the effects of exposure to lead as plumbism. In other eras it has been called saturnism, colic, dry gripes, dry bellyache, and potter's palsy. Until recently we knew only the acute or chronic manifestations of plumbism. In the discussion which follows these ailments will be referred to as the clinical effects of lead. In the decade beginning with 1960, more subtle manifestations of lead hazard became the subject of much speculation and concern within the medical-scientific community. The subtle manifestations of lead intoxication will be referred to as the subclinical effects of lead on man.

Lead can enter the body through the respiratory system, or by way of the gastrointestinal tract. It is also possible for certain lead compounds to be absorbed through the skin. Lead in sufficient dosage can affect the gastrointestinal, excretory, nervous, and circulatory systems in man (Legge and Goadby, 1912:62). Acute clinical manifestations of plumbism are: (1) intestinal colic (commonest and most painful), (2) lead encephalopathy, (3) attacks of coma, (4) delirium, and (5) convulsions. Chronic forms of plumbism are: (1) mental dullness, (2) inability to concentrate, (3) poor memory, (4) headache, (5) deafness, (6) wrist drop, (7) a blue line on the gums, and (8) transitory pains in muscles and joints (Hunter, 1957:235-242). Because the only requirement for possible incorporation of lead into the body is exposure to the metal or one of its compounds, lead poisoning can affect the general public as well as industrial workers.

Ancient man used lead without understanding its toxic properties. He mined and reduced lead from ores by smelting and parted silver, commonly associated with lead, by cupellation, prior to 2000 B.C. (Agricola, 1950:354). Leaden objects have been found in Egyptian tombs. The Assyrians used rods and lumps of lead for currency. In Greece and Rome, lead had a variety of uses; as a component of water pipes and solder, to extract silver from gold and copper, and to glaze pottery. The Assyrians, in about 700 B.C., used lead oxide as a base for the first glaze which would adhere to baked clay (Taylor, 1957:61). Yellow and black pigments were made with lead. White lead for white pigment was made at least as early as the fourth century B.C. by a process which lasted in a modified form until the twentieth century (Taylor, 1957:83).

Although in this early age of metal usage there did exist some association between lead and disease (Hippocrates in 370 B.C. described [Hunter, 1957:219] a severe attack of colic in a man who extracted metals and recognized lead as a cause of the symptoms) the ancients paid little heed to the diseases associated with lead usage. By modern standards the ancients used an infinitesimal amount of lead. When disease did occur it remained largely ignored because workers were slaves and forced laborers.

During the middle ages lead was used for cisterns, pipes, roofing, extraction of silver and gold from copper, glazing pottery, and to make clear glass. The economic and technological development of this period is reflected in the fact that lead poisoning affected miners and metal workers. Hunter (1957:219) noted that ". . . the possibility that occupational factors could be of importance in explaining a given illness was ignored all through the dark ages." Perhaps because plumbism affected only a few who were members of a submerged class, it received little attention.

The amount of lead produced and its utilization grew and changed with the centuries. By the sixteenth century Agricola and

Paracelsus imparted some information related to the diseases of lead miners and lead workers.

In 1556 Agricola published his classic encyclopedic treatise on the mining and metal industries, *De Re Metallica.* Although the work described mining and metallurgy processes, there are incidental but excellent descriptions of ills and accidents to workers, particularly in Book Six. Agricola wrote about mining, smelting, assaying, and extracting ores, including lead. The arts and sciences necessary for a miner to be acquainted with included, according to Agricola, (1950:3-4) ". . . medicine, that he should be able to look after his diggers and other workmen, that they do not meet with these diseases to which they are more liable than workmen in other occupations, or if they do meet them, that he himself may be able to heal them or may see that doctors do so." Agricola also noted (1950:5) that mining is a ". . . perilous occupation to pursue, because miners are sometimes killed by the pestilential air they breathe. . . . Of the illnesses, some affect the joints, other the lungs, some the eyes and finally some are fatal to men."

In 1567, eleven years after the publication of *De Re Metallica.* Theophrastus Bombast von Hohenheim, usually known as Paracelsus, published *Von der Bergaucht und anderen Bergkrankheiten (On Miner's Sickness and Other Miner's Diseases).* Paracelsus presented his observation of diseases of miners and the effects of various minerals and metals on the human organism. In this unique sixteenth-century work. Paracelsus recognized two groups of diseases which affected miners and smelterers: (1) diseases of the respiratory organs, and (2) pathologic conditions resulting from ingesting or inhaling poisonous metals. He recognized poisonous effects of various metals and differentiated between acute and chronic poisoning. Paracelsus wrote, (Rosen, 1943:67-70) "The miner's sickness is . . . the disease of the miners, the smelterers, the pitmen and others in the mines. Those who work at washing, in silver or gold ore, in salt ore, in alum and sulfur ore or in vitriol boiling, in lead, copper, mixed ores, iron or mercury ores, those who dig such ores succumb to lung sickness, to consumption of the body, and to stomach ulcers, these are known to be affected by miner's sickness."

In 1614, Martin Pansa, a physician, wrote and published *Consilium Peripneumoniacum,* (Rosen, 1943:98) or "a faithful guide in the troublesome mine and lung sickness, in which is presented the most important causes of such ailments, the poisonous ones, which arise from the mine, as well as the common ones which come from the fluxes, before that, however, how man may be compared with the small world and with the mine, and finally, how diseases are to be expelled." The book proposed to teach miners how to protect themselves from the diseases to which they were subject. Pansa wrote (Rosen, 1943:99), "All those who dig gold or silver ores, salt, alum, sulphur, lead, copper, tin, iron or mercury are subject to it (disease)." He described causes of disease, symptoms, and treatment.

Agricola, Paracelsus, and Pansa exhibited early concern with the hazards of mining, and incidentally with lead, but few physicians concerned themselves with the health hazards associated with lead mining and smelting. The usage of lead in a pre-technical society was, relatively speaking, minimal, and the number of workers affected was small. In all cases, the benefits of mining and using lead apparently outweighed the risks.

In the seventeenth century, Vernatti, a physician, noted the effects of lead poisoning upon white lead makers. He observed (Taylor, 1957:84), "The Accidents to Workingmen are Immediate paine in the stomach, with exceeding Contorsions in the Guts and Costivness that yields not to Cathartics . . ."

Bernadino Ramazzini, a physician and professor at the University of Modena and later Padua, made a significant contribution to occupational medicine in the eighteenth century. He considered occupational health socially important and undertook a study of the morbid conditions caused by certain occupations, calling attention to the practical application of his knowledge. He stressed the need to study the relationship between occupation and disease, and to account for social and occupational factors, as well as medical factors, when dealing with patients. Ramazzini (1964:7) said, "For we must admit that the workers in certain arts and crafts sometimes derive from them grave injuries, so that where they hoped for a substinance that would prolong their lives and feed their families, they are too often repaid with the most dangerous diseases and finally, uttering curses on the profession to which they had devoted themselves, they desert their post among the living." Ramazzini (1964:53) wrote of fifty-four different occupations associated with lead poisoning and described some of them in the sections concerning potters and painters. "During this process [i.e., potting] or again when they use tongs to daub the pots with molten lead before putting them into the furnace, their mouths, nostrils, and the whole body take in the lead poison that has been melted and dissolved in water; hence they are soon attacked by grievous maladies. First their hands become palsied, then they become paralytic, splenetic, lethargic, cachetic and toothless, so that one rarely sees a potter whose face is not cadaverous and the color of lead." With regard to treatment of workers, Ramazzini (1964:39) noted, "It is hardly ever possible to give them any remedies that would completely restore their health. For they do not ask for a helping hand from the doctor until their feet and hands are totally crippled and their internal organs have become very hard; and they suffer yet from another drawback, I mean they are very poor. . ."

In the nineteenth century Tanquerel de Plances observed that the characteristic traits and primary effects of plumbism could be observed in men who worked in an atmosphere of lead and dust fume.

At the same time that physicians associated lead with toxic effects in workers in mines and industries, it also affected unsuspecting members of the general population. "Dry gripes" was associated with one of colonial America's early industries, rum distillation. Distillation in lead worms and still heads contaminated large quantities of rum. In 1723 Massachusetts colony passed (McCord, 1953) "An Act for Preventing Abuses in Distilling of Rum and Other Strong Liquors with Leaden Heads or Pipes," perhaps to ensure that New England would not lose its rum market. Pewter, an alloy of tin and lead, was commonly used in the seventeenth and eighteenth centuries; pewter utensils such as teapots, mugs, creamers, tankards, platters, basins, and pitchers came into contact with food. Pewter and lead poisoning were often characterized by the common ailment "dry gripes." Periodicals carried advertisements for cures. One such ad read (McCord, 1953:19), "For the Good of the Public, a certain Person hath a secret Medicine which cures the Gravil and Cholick, immediately, and Dry Belly Ach in a little time; and restores the Use of the limbs again, (tho of never too long continuance) and is excellent for Gout. Enquire of Mr. Samuel Gerrish, Bookseller, near the Brick Meeting House, over against the Town House in Boston. N.B. The Poor who are not able to pay for it may have it gratis."

The Devonshire colic epidemic, one affecting the general public, raged for approximately one hundred years until, in 1776, a physician, George Baker, published an essay entitled *Concerning the Cause of the Endemical Colic of Devonshire.* The dangerous disease, colic, was common in Devonshire, a cider-drinking area of England. Baker's essay demonstrated that the "colic" was attributable to lead poisoning. Lead entered the bodies of the cider-drinking population of Devonshire because of extensive, reckless use of lead in the apparatus of cider making and storage. Baker determined that large milestones were hewn into segments and bound together with lead. At the end of his essay, Baker stated (1958: 58-59), "May I presume to hope, that the present discovery of a poison, which has for many years exerted its virulent effects on the inhabitants of Devonshire, incorporated with their daily liquor, unobserved, and unsuspected, may be esteemed by those who have the power, and who have opportunities to remove the source of such much mischief, to be an object worthy of their most serious attention."

Although it was known since ancient times that lead had toxic properties, physicians used a variety of lead preparations for therapeutic purposes. During the eighteenth and nineteenth centuries physicians believed that lead in proper dosage could cure many ills. A medical dictionary published in 1745 (James, 1745: III) discussed the medicinal virtues of lead. "Both in its crude state and in all preparations, lead seems to be cooling, thickening, repelling, absorbing, and contracting so as to retard the circulation of the blood, hinder all secretions and hurt the nerves, by causing spasms, convulsions, tremblings, difficulty in breathing and suffocation. Whence it appears unfit for internal use in any large dose; and, accordingly its medical uses are principally external." The author of the dictionary then suggested that lead, disolved in a mild acid such as vinegar, might be used to cure running and ulcerous sores or skin diseases. Some encyclopedias of the eighteenth and nineteenth centuries counseled cautious use of medicinal lead. The *Encyclopedia Britannica* (1797:742) stated, "The internal use of lead is certainly dangerous, though it is often prescribed in medicine; and even the external use of it is not altogether safe." *Rees Encyclopedia* (1819) cautioned that the remedy often proved worse than the disease, but suggested that externally applied ointments and plasters containing lead had a sedative, drying and repellent quality. A medical treatise written in the early nineteenth century (Semmes, 1801:12-13) claimed that lead therapy could cure consumption, diabetes, dysentery, and epilepsy. The author stated, ". . . lead like all other powerful medicines when given in too large quantities, becomes a poison; but, we have the authority of many respectable physicians, for asserting that its cautious internal exhibition, may be practiced with perfect safety, and frequently with the greatest advantage to the patient." In the mid-nineteenth century lead was still being used to treat consumption (Gray, 1841-42:123). It is a paradox that while the hazards of this metal, both to the working population and the general public, grew increasingly apparent, it still retained its place as a medicine.

All of the observations of the association between lead usage and the risk of poisoning were severely limited by a lack of knowledge of the disease proper and the still relatively limited use of lead.

Lead usage reflects the growth of technology and industry. As industry grew, so (Kranzberg and Purcell, 1967:367) did a "demand for a wide range of metals to meet new needs and the growing ability of industry to provide them." By the first quarter of the twentieth century, upward of 110 industries used lead in some form (Kober and Hayhurst, 1924:413). When the hazard associated with lead affected large numbers of people it received more attention. Nineteenth-century problems of a growing industrial and urban society were so vast, and the industrial workers were beset with so many problems (such as horrible factory conditions, low wages, long hours, child labor, and economic insecurity) that lead poisoning was not foremost among their grievances.

Four factors account for renewed and vigorous interest in health hazards due to lead in the twentieth century. They are: (1) increase in lead usage, (2) more data relative to the incidence of lead poisoning, (3) better medical understanding of the lead hazards and the disease proper, and (4) a change in social attitudes. In the twentieth century, pioneers in the field of industrial health, well aware of the great incidence of plumbism in American mines and factories, spearheaded an effective battle for health legislation to provide more salubrious factory conditions. They made valuable contributions to the knowledge of the action of lead on the body, the prevalence of occupational plumbism in various trades, the period of exposure before poisoning occurs, the different forms which the intoxication assumes, and the dangers which must be guarded against to protect workers in lead trades. In their classic work, *Lead Poisoning and Lead Absorption*, Thomas Legge and Kenneth Goadby used experimental and statistical evidence to show that inhalation of dust caused lead poisoning. In his preface to the volume, the editor stressed the extensive utilization of lead by industry. "This volume deals with a subject of wide interest, for lead is dealt with in so many important processes of manufacture — in the making of white lead; pottery glazing; glass polishing; handling of printing type; litho-making; house, coach and motor painting; manufacture of paints and color; file making; tinning of metals; harness making; manufacture of accumulators, etc." (Legge and Goadby, 1912:V). He noted "Lead intoxication, on account of the great variety of industries in which the metal or its salts are used, is the most prevalent of occupational diseases."[2]

During the first two decades of the twentieth century, a few deeply interested individuals stimulated government to take some action to control lead poisoning in industry. Alice Hamilton, a physician and one of the most outstanding reformers, pursued medical problems and also stressed the human and social problems associated with health conditions in industry. She described herself as a pioneer in an unexplored field of American medicine, the field of occupational diseases. In 1910 she started her investigations of lead hazards as a member of an Occupational Disease Commission appointed by Governor Deneen of Illinois. In 1912 she undertook a similar survey for the United States government. Alice Hamilton studied the following lead-associated industries: (1) manufacture of white lead, litharge, orange mineral, and red lead, (2) glazing and decorating of white ware and sanitary earthenware and tiles, i.e., art and utility ware, tiles, and porcelain, (3) lead mining, (4) lead smelting and refining, (5) the manufacture of storage batteries and accumulators, (6) the painter's trade, and (7) the manufacture of rubber goods. In her autobiography (Hamilton, 1943:124) she spoke of her concern with plumbism. "Every article I wrote in

[2]It is difficult to find accurate data on incidence of plumbism in America, because there was no system of sickness insurance, nor uniform factory inspection as there was during this period in Great Britain. Some available statistics are: (1) Lead Mining in Utah in 1919 and 1920 there were 468 cases of plumbism (quoted from Aub et al. (1926:233). (2) Smelting and refining in 1913, 1,770 cases in 19 plants employing 7,500 men (quoted from Aub et al., (1926:233). (3) State of Ohio, July 1913-November 1914; 514 positive cases of lead poisoning and 138 tentative cases in 48 industries (quoted from Kober and Hayhurst, 1924:459).

those days, every speech I made, is full of pleading for recognition of lead poisoning as a real serious medical problem."

Efforts of pioneers in the field of industrial medicine, social legislation, the rise of unions, scientific knowledge, and new engineering devices have all tended to reduce the hazard of lead. Successful efforts to "clean up" lead industries have made the evils of excessive industrial lead poisoning an event of the past.

The successful efforts employ two essential principles of in-plant safety. The first is that there is a systematic dose-response relationship between severity of exposure to the hazard of lead poisoning and the degree of response in the exposed individual. As the level of exposure goes down, there is a graded decrease in the risk of injury. The risk becomes negligible when exposure falls below certain tolerable levels. These principles assert that agents such as lead can be dealt with safely and therefore do not have to be eliminated completely to keep industrial workers safe (Hatch; 1968:1): "The dramatic successes over the past half century in the control of occupational diseases in many industrial establishments attest to the validity of these principles (stated above) and the very operation of many chemical and other plants in which there is, of necessity, some contact with potentially dangerous agents is justified only on the grounds of continuing demonstration that such work situations are not, in fact, impairing the worker's health." This, then, is the philosophical basis for ideas which prevail today in industrial health. The hazards of lead poisoning are considered controllable to an acceptable degree because lead is essential to industry. The risks, because of control methods, have been reduced in the opinion of the majority of the professionals in occupational health, to a tolerable level.

However, in the 1960s, scientific, social, and economic changes and a proliferation of lead products resulted in a new concept of risk associated with the usage of lead in our society. This concept raises questions relative to subclinical effects of lead in man. A segment of the professional community is suggesting that the criteria used to judge the risk, i.e., clinical symptoms of plumbism, are inadequate. The arguments and data introduced by the advocates of this new philosophical and scientific approach to lead usage in our society will now be examined.

The modern concept about lead hazard stems from new and varied uses of lead, which distribute it as never before throughout the environment and expose the worker and the general popula-

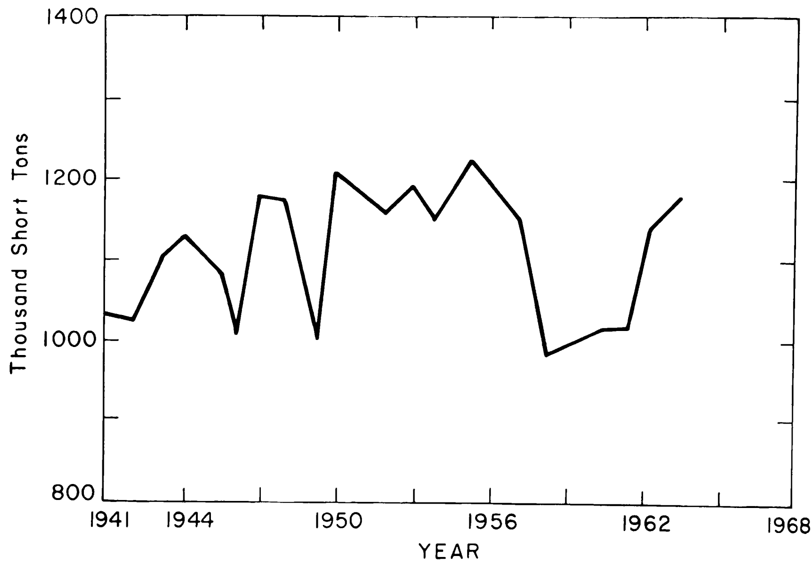

FIG. 1. Lead consumption in the U.S., 1926-1963

tion. Trace quantities of lead can be found in food, beverages, and in the air we breathe. The sources are industry, smelting, incineration, combustion of coal, and motor vehicles. These trace quantities of lead permeate all aspects of the environment, including vegetation and small living animals. Motor vehicles have been an increasing source of lead in the atmosphere since tetraethyl lead was introduced as an additive to gasoline in 1923. Figure 1 indicates annual United States consumption of lead from 1941 to 1968 (Committee on Public Works, 1966:119). The changes in the uses of lead during this period are indicated in Fig. 2 (Committee on Public Works, 1966:19). Major lead usage has shifted from metal products and paints to storage batteries and gasoline additives.

In the past, perhaps the most widely accepted criterion for lead intoxication was the concentration of inorganic lead in the blood, usually expressed as mg lead/100 g whole blood. The basis for this criterion is that lead is stored in the body, primarily in the calcareous portion of the bone, and the blood lead is in equilibrium with the lead storage depots. Hence, as increased quantities of lead are stored in the body, the blood-lead level increases. The physician has guided himself by various levels of blood lead as indicators of pathophysiological changes associated with lead intoxication.

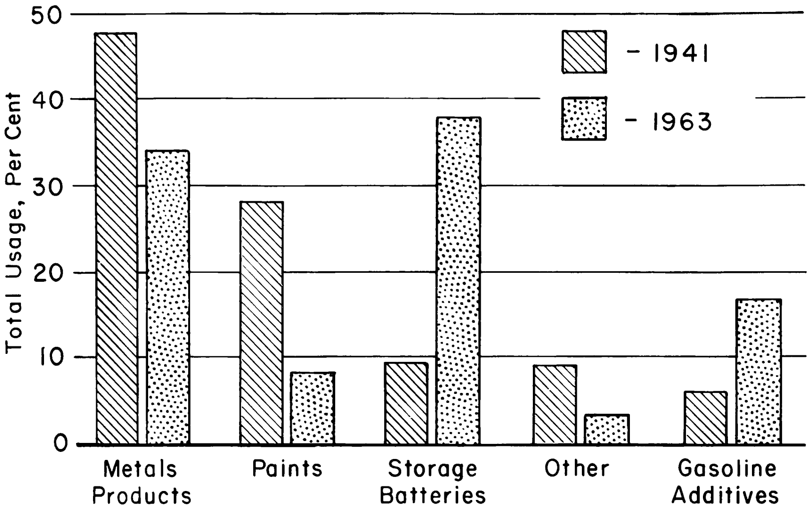

FIG. 2. Shifts in major usages of lead, 1941 *vs.* 1963

As an example, a concentration of 0.08 mg lead/100 g of whole blood has been the guideline for concern in industrial workers. It should be noted that clinical symptoms are very rarely associated with this level. Although the sensitivity of the population at risk differs, clinical symptoms do not usually appear until a level 0.15 mg lead/100 g whole blood is reached (Patty, 1962:953-961).

The advocates of the modern risk concept of lead suggest that certain long-term health effects may occur in the general population exposed to lead from the many sources in the community cited above. They ask the following questions: What is the blood-lead level of the general population? For example, in 1965 the Public Health Service published an often referred to study, *Survey of Lead in the Atmosphere of Three Urban Communities*, which measured blood lead levels in three cities. Concentrations of lead in blood seldom exceeded 0.05 mg per 100 g of whole blood. The concern of the advocates of the new philosophy of risk has nothing to do with the old criterion of blood lead and one might say that an entirely new concept of lead injury has been introduced.

Because of the proliferation of lead products and the resulting introduction of lead into all aspects of our environment, the ability to make more accurate and sensitive measurements and a more concerned attitude toward the welfare and health of the general population, new questions relative to subclinical effects of lead in man have been raised; effects not measurable by any of the guidelines previously used. This new concept of risk, which focuses on trace amounts of lead in vegetation and food supplies, questions the long-term effects of lead in our ecological system. Research performed by Chow and Johnstone, Claire Patterson, and Harriet Hardy illustrate this new concept.

Chow and Johnstone (1965) determined the isotopic composition of lead in antiknock gasolines and in aerosols in the air of the Los Angeles Basin. They also compared the lead-isotope compositions of the aerosols and rural snow from the Lassen Volcanic National Park in California. The isotopic composition of lead in 1963 rural snow was similar to that of Los Angeles Basin aerosols. Therefore, they concluded (Chow and Johnstone; 1965:502-503) that the contamination of the snow was attributable to industrial pollutants. "The high concentration of lead in water of precipitation and that of the surface of the sea can be attributed to automobile exhaust." Claire Patterson studied contaminated and natural lead environments and concluded that residents of the United States today were undergoing severe chronic lead insult, that geochemical relationships and material balance considerations show high ingestion of lead which is excessive compared to "natural" levels, that the lead probably originates from lead dispersed in forms of lead alkyls, lead arsenates, food-can solder, and millions of tons of lead accumulated and stored in past paints, alloys, piping, glazes, and spent ammunition (Patterson, 1965).

Patterson, a geochemist, raised the question of blood-lead levels. He stated (Patterson, 1965:358) that, "existing blood lead concentrations have for decades been regarded as natural, although it is well known that the average value lies only slightly below the threshold levels for classical lead poisoning."

Patterson then suggested that (1) natural and toxic blood-lead levels be defined with greater care than in the past; and (2) that deleterious effects of severe chronic lead insult be further investigated. The dialogue centers on levels of lead in blood and urine, and whether or not long-term exposure to lead leads to chronic ailment.

An epidemiological study of blood levels in the general population and in occupationally exposed groups suggested that increases in atmospheric lead will result in predictably higher blood levels in exposed populations (Goldsmith and Hexter, 1967). The study further stated (Goldsmith and Hexter, 1967:134), "It is clear for many urban residents that the total quantity of lead absorbed from the respiratory tract is of the same order of magnitude as that absorbed from the gastro-intestinal tract, that increased respiratory exposure within the range observed in community air pollution is capable of producing materially increase storage of lead in the body as reflected in the blood lead level, and that further increases in atmospheric level will result in higher blood lead levels in the population in a predictable relationship."

Harriet Hardy, a physician, stated that one approach to examining the potential hazards from low-level exposures to lead was to study identifiable groups in the population—for example, infants (Hardy, 1966). Because growing tissue is more vulnerable to lead than adult tissue, smaller doses are required to produce diagnosable lead poisoning in children. She also noted that there is a likelihood that lead in the body at levels considered to be harmless from industrial experience produces damage, and that if this is true then other insults natural or man made must be assessed in judging what amount of lead is harmful (Hardy, 1966:714). The influence of lead on cell growth, the effects of lead poisoning on mental development, the effects of lead on life span, and the concentration of lead in bone are some of the other questions raised.

The public has been alerted to the dangers of lead ingestion by young children who often eat chips of lead paint which fall from ceilings and walls of substandard and old buildings in ghetto areas. Prior to 1940, lead-based paint was commonly used for interior painting, and many old and deteriorated houses have thick layers of lead paint (King et al., 1972). In children the minimum blood concentration of lead at which poisoning occurs is lower than in adults. The United States Public Health Service recommends that a blood lead concentration of 40 mg or more per 100 ml of whole blood is evidence suggestive of undue absorption of lead (Pediatrics, 1971). It has been estimated that the number of children in the United States with high blood levels of lead is possibly as high as 225,000 (Oberle, 1969). In the case of childhood lead poisoning it is believed that the problem is already defined, and its causes known. Therefore, the public health attitude toward this problem is favorable. For example, the United States Public Health Service is actively involved in developing a program to control lead poisoning in children. In this case there is less controversy than in questions raised by atmospheric pollution.

At the same time that this new concept of lead injury is being explored and redefined, a number of other researchers continue to study lead concentrations in blood and have thus far reached the conclusion that there is not a significant health threat now or in the foreseeable future. *Lead Research: Current Medical Developments*, presented at the 31st Annual Meeting of the Industrial Hygiene Foundation, presented the conclusion (Stopps et al., 1966:5) that "there has not been an upward trend over the past 30 years in either urine or blood lead levels despite a very large increase in the use of gasoline containing antiknock agents." An International Study of Normal Levels of Lead in Blood and Urine was made by the World Health Organization and the Columbia University School of Public Health and Administrative Medicine (Goldwater and Hoover, 1967), which tested 30 subjects in each of 15 collaborating laboratories throughout the world, and studied and suggested normal levels of lead in blood and urine. These levels were compared with tabulated levels over the period 1925-65. Results (Goldwater and Hoover, 1967:61) stated, "Of particular interest is the fact that there is no significant change in the normal blood and urinary level over the past four decades."

As a result of these discussions, lead in the environment has become a controversial public issue. Four important recent documents illustrate the controversy. In January 1965 a study of atmospheric lead in three selected cities was published (United States Public Health Service, 1965). Samples of air were made in locations in each city and amounts of airborne lead were determined by laboratory analysis. Average concentrations of lead in all samples were 1.4 mg per cubic meter of air in Cincinnati, 1.6 in Philadelphia, and 2.5 in Los Angeles. Concentrations of lead in blood of some 2,300 individuals representing the three cities were determined. Eleven persons showed concentrations of 0.06 mg per 100 grams of blood—six parts in 10 million. Concentrations of 0.08 mg of lead per 100 grams of blood are associated with toxic lead poisoning (Committee on Public Works, 1966:130). The study (United States Public Health Service, 1965:19-20) stated "Even though the lead levels for the entire group, with a few exceptions, are within the presently accepted normal range in humans, the data show some interesting gradations. Levels of lead in the blood tend to increase gradually as the place of residence varies from rural to central urban areas. A second gradation is related to increasing op-