DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE
411 West Chapel Hill Street, Durham, North Carolina 27701

NATIONAL AIR
POLLUTION CONTROL
ADMINISTRATION

November 19, 1969

Dr. Jerome Cole
Manager, Environmental Health
International Lead Zinc Research
Organization
292 Madison Avenue
New York, N. Y. 10017

Dear Dr. Cole:

The Bureau of Criteria and Standards, NAPCA, has been given the responsibility for preparing a department position paper on lead which reflects all areas of interest from the ECA, FDA, NAPCA, NIEHS and other HEW departments. The comments received have been compiled in a rough draft and are being submitted to all members of the Lead Liaison Committee for their review prior to the January 20, 1970 meeting.

Two areas are missing in the draft copy. The FDA and the Bureau of Occupational Safety and Health, ECA, have not submitted a report of their program interests and current activities relative to lead due to unavailablity of key personnel during this period. However, Mr. Duggan and Dr. Stokinger plan to send their sections as separate documents by December 1, 1969. When received these should be added to the original draft sent from this office.

I would appreciate a discussion of your comments and recommendations at the Janurary 20, 1970 meeting. It would be extremely helpful if I could recieve the written comments prior to January 5, 1970 so we can make the necessary editorial changes.

Sincerely Yours,

Ronald E. Engel
D.S. Barth, Ph.D.
Director,
Bureau of Criteria and Standards

Attachment

cc: Dr. Horton
Dr. Giel
Dr. Plumlee
Dr. Engel

LEAD AND HEALTH

Introduction:

Many chemical elements are commonly found in small amounts throughout the environment and in all living things. This is particularly true of metals. Lead is one of these ubiquitous metals. These substances which are commonly present but only in small amounts are known as trace elements or trace substances. Some of them, for example iodine, zinc, fluorine and iron are essential for normal animal and/or plant metabolism. Others, although always or frequently present, are not necessary for normal life. Lead is one of the latter group which is not required in normal nutrition and metabolism. The small amounts of these nonessential trace elements which are commonly present have not been found to be injurious to health. Larger amounts of both essential and nonessential trace elements are toxic. In fact almost any substance present in excess is injurious to health.

Lead is not only common in nature, but is very frequently used in many different ways in industry and in consumer goods. Opportunities for exposure to this metal are frequent. It is essential to seek out conditions which cause excessive exposure and to control or eliminate them. On the other hand attempts to eliminate the intake of lead entirely, or to reduce it merely for the sake of reduction would be foolish and wasteful. The optimal approach to the health aspects of lead and other trace elements, on the basis of present knowledge, appears to be: (1) to determine at what level of intake, if any, they are required; (2) to determine at what level of intake they show the beginning signs of toxicity; (3) to establish safety margins so that neither deficiency nor toxicity is at all likely to occur; (4) to attempt to maintain the population intake of each substance within the determined safe zone by means of appropriate technical and administrative methods. We are somewhat familiar with the health problems created by lead due to several centuries of observation and control efforts. Many steps have been taken in the direction of fulfilling the 4 requirements listed above. But further efforts are still needed to refine our knowledge, particularly in items 2 and 4.

Exposure to Lead:

All natural foods contain small quantities of lead because lead is present in all living things. This is now the principal lead exposure of the general population. In the case of some trace elements certain food plants or animal organs store the substance in considerable amounts. This is not known to occur with lead. Only small quantities are found naturally occurring. Food production, processing, preservation and preparation may be accompanied by the introduction of lead since this is a versatile and useful metal. Beverages are also subject to contamination, although they also rarely contain significant amounts of lead naturally. Historically the contamination of food and drink has been the major source of lead poisoning in the general population, e.g. cooking, serving and storing utensils and containers made from metal alloys containing lead, or from pottery glazed with lead compounds. This problem, particularly with pottery, still exists in rural areas of a number of countries. Other historically famous episodes include those induced by (1) lead cooling coils in rum stills (West Indies dry gripes) (2) lead linings and joints in cider presses (Devonshire colic), (3) lead compounds used for clearing and preserving wine (Poitou colic). Item (1) is again a problem in this country due to illicit amateur whiskey production in some areas. Acid foods and beverages are particularly liable to dissolve lead from containers. Foods may also be contaminated by lead containing insecticides e.g. lead arsenate.

Drinking water supplies very rarely contain lead in significant amounts. Soft acid waters will extract metal from lead pipes, whereas hard waters will not do so. Lead plumbing is now rarely used, and was previously not employed with water supplies which might dissolve the metal. However some problems have been found in old buildings with lead plumbing when their water supply was changed from a hard to a lead dissolving type.

Pica is a term applied to the habitual eating of non-food substances such as dirt, paint, plaster, putty, etc. This is a very common activity in preschool children. Pica is partly exploratory in nature, but may be extended and continued as a habit under certain unfavorable personal and social circumstances. Occasionally it remains into adult life. Many of the favorite pica substances, especially paint, contain large amounts of lead. Nearly all cases of childhood lead poisoning are due to pica.

Exposure to lead at work has been a major possible source of excessive exposure, and probably always will be due to the great usefulness of this metal in a variety of ways. Exposure to lead in industry has long been known and has been extensively studied. While most of the severe exposures in the general populace have been from ingestion of lead, those in industry have been largely due to inhalation of lead-containing fumes and dusts produced by heating, pulverizing and grinding. Industrial hygienic measures for controlling worker exposure can be and have been developed for nearly all work exposures. On several occasions in the past large outbreaks of worker poisoning have occurred which were usually due to unrecognized danger resulting from new industrial processes. As our knowledge of lead increases these episodes are less likely to occur. Application of sound industrial hygiene practice is not yet sufficiently extensive with respect to some lead exposures.

Another source of lead exposure is the ambient air. Small amounts of lead are present in the air of all places where people live. The principal source of air lead is the combustion of leaded gasoline in motor vehicles. Lesser amounts are contributed by emissions from lead industries, incineration, and the burning of some coals which contain lead. Air lead is a common source of exposure of the whole population just as food is, but to a lesser extent.

Absorption and Excretion of Lead:

Lead is absorbed principally through the gastrointestinal and respiratory tracts. All of the lead which is ingested or inhaled is not absorbed into the body. Some variation in percent of lead absorbed is due to the chemical and physical characteristics of the material. Absorption from the gastrointestinal tract is rather inefficient, only 5 to 10% of the metal which is taken into the body in this way is absorbed, the remainder being excreted in the feces.

Absorption from the respiratory tract depends mainly on the size of the particles which are inhaled. Experiments with lead inhalation in man (1,2) indicate that a little less than half of the lead in the air breathed in is deposited in the lung when the size of the lead containing particles is about 1 μm in diameter. From these and other studies (3) we know that particles of this size are deposited mainly on bronchial surfaces. They are in the lung for only a few hours before they are removed by ciliary action and swallowed. Only a very small amount of this material is retained and absorbed from the lung. The remainder passes into the intestine and is absorbed from there at the usual low rate. When the lead particles are smaller than 0.4 μm in diameter experiments show that they are deposited deeper in the lung in the alveolar regions. The percent deposited from the inhaled air is probably somewhat less than with the larger particles, about 35-40%, but the percent of those deposited which are retained in the lung and absorbed into the body is greater. With present experimental methods this cannot be determined accurately. A suitable radioactive tracer lead compound would be required and this is not available. Probably 20-25% of the inhaled smaller lead particles are retained and absorbed. Since most of the lead particulate in the ambient air is in this small size range it would be very useful to have more precise information on this point.

Lead is excreted from the body in the feces and in the urine principally. Small amounts of lead are also lost from the skin and appendages through shedding or cutting of cells, nails and hair, and through skin secretions. Under ordinary circumstances with low and relatively constant exposure lead intake and excretion are believed to be equal.

Body Burden of Lead and Lead Injury:

The amount of lead present in the body at any given time is usually referred to as the body burden. Most of the tissues and organs contain some lead. The amount varies from one tissue to another. Bone content of lead is high and the skeleton contains a large part of the lead in the body. The total body burden can only be estimated. At ordinary relatively constant levels of intake many tissues have a rather steady average lead level. This is different for each tissue. In practice it is customary to use the lead level in a readily accessible tissue such as blood as an index of the body burden. The level of lead excretion in the urine is also sometimes used because the specimens are so easy to obtain, but the variance is higher than with blood levels under similar conditions, which makes the information obtained more difficult to interpret. Blood lead levels in individuals who have no known high exposure are found to fall between 10 and 30 µg per hundred grams of blood. Overexposed individuals may have very high blood lead levels, frequently over 100 µg.

When exposure levels are high lead poisoning may result. Symptoms and signs commonly found are severe abdominal cramps, anemia, paralysis of some motor nerves and encephalitis. The latter symptom is particularly apt to occur in childhood cases, and may leave permanent residual damage after exposure has ceased. Prolonged industrial and other experience with lead poisoning indicates that clinical disease of the type described above does not occur at blood lead levels below 80 µg per 100 gm. of blood.

Clinical disease means illness which is apparent to the patient and his physician. Most readily apparent sickness is preceded by a milder disturbance which is frequently referred to as subclinical illness. This indicates that some signs of disturbance can be found by appropriate laboratory or other tests, even though the person does not feel ill. While our knowledge of clinical lead poisoning is extensive and well established, our understanding of subclinical injury is quite limited.

One of the principal forms of lead injury is found in damage to the blood forming system. Both the production of hemoglobin and the production of the red blood cells are disturbed. While anemia has not been shown to occur from blood lead levels under 80 µg it appears possible from recent work on hemoglobin formation and red cell survival that some signs of less serious disturbance can be detected below this level. The examination of the urinary excretion of delta-aminolevulinic acid appears at present to be particularly promising for the study of subclinical effects. Other substances are also being evaluated. Considerable research is being done in this field. It should improve our knowledge considerably. It is possible that a lower injury threshold than 80 µg will be indicated, but the fragmentary results which are currently available indicate that it will not be very much lower. There is currently a great deal of skepticism regarding the existence of toxic thresholds. At present there is no evidence available to indicate that the firmly established concept of a toxic threshold for lead is incorrect.

In contrast to the rather considerable active searching for subclinical effects in the blood forming system there has been almost no activity of a similar nature in relation to the nervous system, liver, kidney etc. This is an important deficiency which should be remedied. Other deficiencies in our knowledge appear to be of two main types. One is the lack of information regarding possible delayed or chronic effects of lead from most levels of exposure, especially moderate levels, above average but not producing poisoning. Clinical lead poisoning is an acute or subacute illness. Very little effort has been expended in followup study of exposed and poisoned groups to determine their health status twenty to fifty years later. The few available studies are contradictory. The second important deficiency is our lack of information on the presence or absence of individuals in the population who are especially susceptible to lead, and therefore might show injury at lower levels of exposure than most of us. No such persons are known at present, but very little effort has been made to study this problem. If such susceptibility exists it might be permanent e.g. due to a metabolic abnormality, or temporary e.g. due to a period of growth, pregnancy, or illness.

At the present time the Public Health Service is supporting one study on subclinical toxicology which will examine a number of hematologic parameters in relation to exposure and body lead levels. It is also supporting two followup studies of groups with previous high lead exposure. Next year a symposium will be held to consider some of the deficiencies referred to above and to recommend methods of study for correcting them. This will be jointly sponsored by the Public Health Service and interested industrial associations. In addition to these efforts the National Institute of Environmental Health Sciences is both supporting and conducting studies in the basic nature of lead injury to the cells of selected organs and tissues.

LEAD POISONING IN CHILDREN

Introduction:

Lead poisoning in children is of grave concern to public health officials not only because of the deaths that occur, but also because of the permanent central nervous system disorders that can arise from serious exposure. While lead poisoning is not uncommon, it often goes unrecognized because its symptoms are similar to those of other diseases. Delay in diagnosis often leads to continued exposure resulting in death or disability. One indication of the seriousness of the problem is the fact that while lead poisoning accounted for only 4.7 percent of the accidental poisonings in children reported to the Chicago Board of Health in the 3-year period 1959-1961, it was responsible for 79.0 percent of the total accidental poisoning deaths during that time.[4]

Nationally, the picture is not as clear. It is estimated that between 60 and 100 people die each year and between 3,000 and 10,000 suffer some disability due to lead exposure. The number of individuals with elevated lead levels may be many times greater. The difficulty arises from the fact that only certain cities and certain hospitals within these cities are looking for and reporting cases with high body lead levels.

According to death statistics issued by the Department of Health, Education, and Welfare, there were 98 deaths in 1960[5] and 61 in 1966[6] in the United States due to accidental poisoning by lead and its compounds. Age distributions were not given.

Much has been written on the subject of lead poisoning, especially as it pertains to children. The problem is known, as are many of the circumstances surrounding it. The tasks are to prevent dangerous intake of lead, to detect high levels when they occur and to begin timely institution of effective therapy when children are found to have elevated lead levels.

Many of the environmental, sociological, and psychological factors surrounding childhood lead poisoning have been described. Lead poisoning in children is associated with the eating of paint chips or with gnawing and chewing painted surfaces. This behavior is known as pica, i.e., the habitual, purposeful, and compulsive search for and ingestion of unnatural food substances. These include dirt, paint chips, plaster, putty, clay, paper, laundry starch, matches, and other substances.

A theory that nutritional deficiency is etiologically related to pica was proposed but could not be demonstrated in a study of urban children in Washington, D. C.[7] It was noted in this study that Negro families who had recently moved from the South to Washington seemed to be afflicted most frequently. This was explained as a reaction to the economic and social stress of new surroundings. Many have stated that pica is the usual forerunner of lead poisoning. This observation suggests that lead poisoning should be specifically looked for whenever a history of pica is noted. Bradley et al[8] stated that approximately 70 percent of children with high blood lead levels had a history of pica. The authors considered this to be under-reporting, possibly resulting from parents' failure to observe the act, or reluctance to admit such behavior. Chisolm and Kaplan[9] stated that the relationship of mother and child "is often a critical determinant of pica." Approximately 50% of the mothers of these children with pica exhibited pica themselves. The child may use pica as a method to relieve anxieties or tensions brought on by an absent or ineffective mother, i.e., a working mother or one with emotional difficulties, or one unable to cope with family responsibilities. Pica also may be a means for the child to gain attention. Males and females aged 1-5 years are the main victims.[10] These are the ages when children explore their environment by mouthing objects.

Negroes and Puerto Ricans have a high incidence due to economic and social factors. These result in having to live in what can be referred to as the "lead belt"--that part of the city where homes are old and housing conditions have deteriorated. In such dwellings maintenance may have long since lapsed; the paint, many layers thick, is chipping and plaster is falling. Children left alone by working mothers or otherwise may turn to oral gratification due to emotional deprivation.

One of the main factors in childhood lead poisoning has been the use of a lead-base paint. Many of the poisonings can be attributed to intoxication from interior paint applied prior to 1940. In 1940 legislation was passed which limits the lead content of interior paints to one percent. Many older buildings continue to be sources of the high lead content paint used prior to this date. Even when repainted frequently, flaking and chipping of paint and plaster results in paint chips with a high lead concentration. While materials other than lead are used as a base for interior paints, many exterior paints still contain a large amount of lead.

Diagnosis:

The diagnosis of lead poisoning in children is frequently overlooked especially in the early stages. This is because of low index of suspicion on the part of some physicians due to the vagueness and ambiguity of some of the symptoms. Early symptoms and signs may include loss of appetite, weight loss, constipation, fatigue, headaches, weakness, anemia. Subsequently, the patient may develop intermittent vomiting, irritability, nervousness, lack of coordination, and vague pains in the arms, legs, joints, and abdomen. Very severe symptoms include persistent vomiting, elevated blood pressure, delirium, convulsions and coma.

A number of laboratory tests or screening processes have been used as an aid to diagnosis of lead poisoning. One, a urine test, determines the amount of coproporphyrin in urine. Coproporphyrin is a product of body metabolism. High urine levels may indicate lead poisoning. However, the test is not specific and may yield either false positive or negative results. Delta-aminolevulinic acid (ALA) in urine is also high in lead poisoning and is more specific. Quantitative diagnostic ALA urine tests require 24-hour urine samples. In young children this is often very difficult to obtain. Blood lead determinations are a more reliable and widely accepted test. Chemical analytic methods for determining blood lead levels can take between 24 and 48 hours. Also, factors such as hematocrit, intercurrent infection, coincident bone disease, and recent administration of chelating agents can cause some difficulty in interpreting the results by this method.[12] Atomic absorption methods are receiving attention because of the shorter analysis time required for this technique. Jacobziner suggested that a blood lead level of 0.06 mg/100 ml or more with the presence of two or more symptoms of intoxication be considered a positive test for lead poisoning. Even when no symptoms are present, he suggested that the possibility of lead poisoning remains and that periodic blood lead determinations should be carried out.[11] Recent recommendations by the Subcommittee on Accidental Poisoning of the American Academy of Pediatrics state, "where blood lead concentration lies between 60 and 80 μg percent of whole blood and there is hemotologic evidence of lead toxicity but no clinical symptoms" treatment should be given.[13] A third method of analysis is the use of hair samples. Hair concentrates more lead per unit weight than other tissues or body fluids. It has been reported that the concentration of lead in the hair nearest the scalp may exceed that of more distal samples following severe exposures. Chronic exposure of relatively long duration results in elevated levels throughout the total length of the hair sample.[14]

X-rays aid in determining chronicity of the condition. Lead lines may be present in the knees, wrists, or long bones of those with lead poisoning. X-rays of severe cases in children under two years of age, however, are often negative, even though they may be affected. In cases of recent ingestion of lead, flat films of the abdomen may reveal the presence of radio-opaque particles in the gastro-intestinal tract.

Treatment:

A comprehensive review of therapy in lead intoxication has recently been published by Chisolm.[15] The treatment involves deleading by chelating agents, singly or in combination, and supportive therapy.

Control and Prevention:

Control and prevention include educational campaigns directed at both medical personnel and at the general public. The type of educational program used will depend upon the target population. Physicians should be reminded of the signs and symptoms, the relation of pica to lead paint, and diagnostic procedures. Physicians working in areas where lead is a known problem should be specifically alerted. Other public health workers (nurses, sanitarians, etc.) and other allied professionals (building inspectors) also should be made aware of possible sources, signs and symptoms of lead poisoning and its relation to pica.

Those living in "lead belt" areas are a second important target population for the educational campaign. Emphasis should be on the problem, its causes, signs, symptoms, possible sources of intake, and the proper action to be taken should exposures or lead poisoning be suspected. The educational program must be written in easy-to-understand language. Success of an educational campaign in this area could be evaluated by noting the number of suspected cases or sources brought to the attention of physicians and health authorities.

A second approach involves sample surveys in various areas of the city. Children (age 1 to 5 years) of small segments of a population, living is suspected areas, can be tested for lead content of blood. Detailed follow-up investigations may then be launched in areas of the city where positive results have been noted through the survey technique. Subsequent investigations may involve other age groups in the population at risk. When a symptomatic child is found in the clinic, an epidemiologic investigation of the case should follow as is done for a communicable disease. Children who may have had similar exposure with respect to time and place should be tested for lead body burden.

Where preliminary surveys have identified potential cases, detailed home surveys should be launched to determine the presence of lead in paint, plaster and other potential sources. The lead content can be determined by scraping and collecting samples of paint and the samples tested to determine if more than one percent of lead is present. Test methods include standard analytical chemical techniques; atomic absorption; a low intensity radioisotope device for surveying interior surfaces; and ultra-violet flourescent methods. Reports as to effectiveness of the value of the methods vary. The UV flourescent technique fails to detect lead at sufficient depth below the surface. Present methods of dissolving paint in strong acid are not suitable for measurement of the dissolved sample in the atomic absorption device. The New York City Health Department has commented on their experience with the radioisotope screening device. In its present state of development, it is too heavy to be practicable, its target area on the surface for each reading is small and many readings are necessary to complete a survey.

There is a need for definition of the term "lead poisoning" in order to ensure uniform reporting of the condition from poison control centers and other health and safety organizations. Such a standard authoritative definition is also necessary for successful enforcement of laws and ordinances for protecting the public. With an established definition of lead poisoning, differentiation can be made between poisoning and unnecessarily high lead body burdens. Reporting of the latter, which can be done in quantitative terms, is very important for operation of preventive or control programs.

Legislation and Enforcement

The important parts of any action program are proper and effective legislation and suitable enforcement.

Building and housing codes in most cities contain general provisions requiring maintanance of interior surfaces and prohibitions against the use of toxic materials. In some of the cities which have recognized the problem of lead poisoning of children from paint, additional, more stringent provisions have been added. Two examples are given below:

a. The City of Baltimore Housing Code[16] provides:

"706. Painting

All interior loose or peeling wall covering or paint shall be removed and the exposed surface shall be placed in a smooth and sanitary condition. No paint shall be used for interior painting of any dwelling, dwelling unit, rooming house or rooming unit unless the paint is free from any lead pigment."

b. The City of Chicago in 1968 adopted an even more stringent code.[17] This code requires:

"78-17.2.(d). All interior walls, ceilings and interior woodwork shall be free of flaking, peeling, chipped or loose paint, plaster or structural material.

If, upon inspection by the Commissioner of Buildings, or his duly authorized representative, there is found the presence of flaking, peeling, chipped or loose paint, plaster or structural material in any building being used for housing, the Commissioner of Buildings, or his duly authorized representative, is hereby empowered to secure specimens of flaking, peeling, chipped or loose paint, plaster or structural material and to analyze or cause an analysis to be made determining whether or not the materials contain lead or its compounds.

In any case, where analysis reveals the presence of lead or its compounds in a quantity of more than one percent, or in a quantity sufficient to be a hazard to health and safety to the occupants of the family unit, the Commissioner of Buildings shall order the owner or his agent to remove all materials containing lead compounds or cover such surfaces with an acceptable covering having a flame spread rating not to exceed 15. All covering shall be securely attached to a smooth and sound surface."

The specific provision included in the Chicago ordinance requiring removal or effective covering of all lead-base materials is an essential which is not covered by most city codes.

Some possible consequences of legislation warrant consideration:

a. At present, strict enforcement of lead control ordinances may result in owner abandonment of the property or refusal to rent to families with small children.

b. The aim of housing and health officials should be to stimulate a cooperative spirit between renter and building owner. Homes, apartments, and other structures should be kept in good repair so that loose or chipping paint or plaster can be eliminated, reducing exposure to the hazard.

c. Urban renewal and redevelopment programs are eliminating many old dwelling units. However, these programs often affect only limited areas and may take years to complete. Additional action is needed.

d. Some consideration is being given to Federal support to local communities in dealing with the problem of lead poisoning from paint.

Current and Future Research:

There is a definite need for ongoing research in lead poisoning. A better understanding of the behavioral problems which make possible lead intoxication in the child is needed, as well as the development of methods of altering this behavior.

The development of more accurate and rapid screening and diagnostic tools is needed to pinpoint the problem in environmental areas and in population groups.

Means for deleading an environment rapidly and at low cost, and without danger to those responsible for the deleading, as well as others, are needed.

Recommended Actions:

1. Establishment of a uniform definition of what constitutes a case of lead poisoning.

2. Research to determine building materials which can be used economically to effectively cover painted surfaces containing lead, or methods of removing lead paint from home environments.

3. Provision of regional laboratories by the Federal Government to provide rapid and reliable tests to support local control programs.

4. Official recommendation to local jurisdictions to make lead poisoning a reportable disease in areas likely to have a problem.

5. Provision of more lead treatment centers in high incidence areas.

6. Determination of means to ensure that welfare funds used for rent or home repair are not supporting housing having a lead hazard to children.

7. Stimulation of research in the areas previously alluded to.

LEAD IN AMBIENT AIR

SOURCES OF LEAD IN THE ATMOSPHERE.

Lead is used in a large variety of processes in this country. In 1968 over one million tons of lead were consumed as shown in Table 1.

From the standpoint of air pollution lead sources may properly be divided into four major categories which are discussed below.

Production and Reprocessing of Lead Metal.

The numerous smelters scattered over the country which are the producers of the basic metal must be contributors of lead to the atmosphere. The percent of the metal produced which is emitted into the air is not known, therefore, the total contribution cannot be computed. Although the larger and heavier particles settle out within a short distance from the smelter the smaller particles may be carried great distances depending on particle size and meteorological conditions.

Secondary smelters or lead recovery plants which process scrap and recover lead metal emit particulates into the air in varying quantities depending on effectiveness of control methods employed. Most of the recovery plants are located in urban areas and may be significant contributors to the lead problem in some communities. Such discharges may contain as much as several milligrams of lead per cubic meter of air. Examples of concentrations of lead in in-plant air that may be discharged to the outside are shown in Table 2. All of these discharges are not continuous, but may be produced intermittently.

Industrial Sources.

The large tonnage listed as other in Table 1 indicates many uses for lead that are difficult to trace. While the consumption of lead has been rather stable during the last 10 years, there have been changes in the amounts consumed by various industries; the amounts of lead used for sheathing cable and for production of paints, for example, have decreased in the last decade because of the introduction of new materials.

Lead and its products are often processed from the molten state, sometimes giving rise to fume when thermostatic control is not present. Many lead products may also be produced as powders or involve products produced from powdered materials that may be dispersed into the air. The in-plant hazard associated with the processing of lead is often recognized, and most industries control this hazard. Although some lead is removed from industrial discharges by control devices, lead-bearing dusts and fumes escape to the outside air.

Automotive Sources.

One of the major sources of lead to the atmosphere is the exhaust from gasoline-fueled vehicles. Essentially all of the motor gasoline sold in the United States contains alkyl lead compounds added to improve the antiknock quality of the fuel. During combustion, these organic lead compounds undergo thermal and oxidative breakdown and are discharged in the exhaust as inorganic lead salts. Until 1959 the only alkyl lead compound used commercially was tetra-ethyl lead, although the ability of other alkyl lead compounds to increase antiknock quality was known. The relative effectiveness of the various alkyl lead compounds in imparting antiknock quality to gasoline depends on many factors including, to a large extent, the specific hydrocarbons that comprise the finished gasoline blends. Developments in the technology of petroleum processing in recent years have resulted in significant changes in the number and types of hydrocarbons in many of today's gasolines. Because of these changes and changes in other vehicle factors that also influence the type of antiknock quality required, certain refiners now find that alkyl lead compounds other than tetraethyl lead are more effective in raising the antiknock quality of their particular fuels. Antiknock compounds other than tetraethyl lead currently being used are tetramethyl lead, physical mixtures of a catalyzed redistribution reaction of tetraethyl lead and tetramethyl lead. The amount of each of the alkyls in the latter mixture depends on the percentage of tetraethyl and tetramethyl lead used in the reaction. These alkyl lead compounds are present in today's gasolines in widely varying concentrations, the maximum in motor gasolines being 4.23 grams of lead per gallon (equivalent to 4 milliliters of tetraethyl lead per gallon of gasoline) in accordance with an agreement between the suppliers and users that has the concurrence of the Office of the Surgeon General of the U. S. Public Health Service.

The total consumption of lead metal in antiknock compounds in domestic motor gasolines for a ten year period is shown in Table 3 with the average lead content per gallon during the same period.

Studies of the lead particulates leaving the tailpipe have shown that from 70 to 80 percent of the metallic lead used by a vehicle will eventually be exhausted to the atmosphere over 20,000 to 30,000 miles of city and country driving.[15] The balance remains in the engine itself, in the lubricating oil and oil filter, and in the vehicle exhaust system. The amount and particle size of inorganic lead leaving the tailpipe of a vehicle at any given time is dependent on many factors including the operating mode at the instant, the short and long term type of preceding operation, the age of the vehicle and its exhaust system, and engine and exhaust system design features. These studies have also shown that in city-type operation less lead is exhausted than in highway-type service. In city operation from 20 to 60 percent of the lead burned in the combustion chamber is exhausted from the tailpipe in inorganic form depending upon the amount of lead particulates accumulated in the exhaust system as the result of the preceding operating history. Of this from one-half to three-fourths of the lead is in the particle size range that might be expected to remain airborne.

Although much of the lead discharged by vehicles is exhausted in the form of inorganic particles, varying percentages of the alkyl lead compounds blended in gasoline may reach the atmosphere through escape of fuel vapors. Recent reports from Germany indicate that under stagnation conditions a major portion of the emitted lead may be in the form of lead alkyls. Volatile fuel vapors can be lost from vents on the carburetor and fuel system and are displaced from the tank during refueling. The concentrations of alkyl lead compounds in the vapor are lower than those in the original gasoline since these compounds are less volatile than gasoline and tend to remain behind in the unevaporated portion. Some vaporized fuel containing alkyl lead compounds escapes also in the blowby gases that are forced past the pistons and discharged from the crankcase. (With the installation of positive crankcase ventilation devices, this source will eventually be eliminated.) Moreover, in the normal combustion process a very small percentage of the fuel introduced is not completely burned. This unburned fuel contains some alkyl lead compounds. This lead, however, is mixed with hot exhaust gases and contacts components of the engine and exhaust system at high temperature; considerable decomposition results, since the alkyl lead compounds begin to decompose at temperatures as low as 400°F. All organic lead compounds, even at low concentrations, are light-sensitive and hence are subject to photochemical decomposition once they reach the atmosphere.

Other Sources.

Soils generally contain lead, and therefore particles of soil that become air-borne contribute small amounts of lead to the atmosphere. The lead content of soils varies with the geology of the area. Goldschmidt reported that the average in the earth's crust is 16 ppm. Values of several thousand parts per million may be found near smelters. Cholak and co-workers reported that the lead content of soil in the Cincinnati area varied from 16.4 to 360 ppm.

Coal contains varying amounts of lead. Consequently, air contaminated by fly ash or by soot derived from the combustion of coal may contain appreciable quantities of lead. Concentrations of lead as high as 150 ppm in fly ash and 358 ppm in soot have been reported.

METHODS FOR THE MEASUREMENT OF ATMOSPHERIC LEAD

Collection of Samples.

The most commonly used method for the collection of air particulates for subsequent lead analysis involves filtration through either a glass fiber or membrane filter. The usual practice is to sample for a 24-hour period, although shorter or longer sampling periods may be employed if desirable and an adequate sample is obtained for analysis. Cellulose filters may be used but they are not recommended because of variation in collection efficiency. Particles collected by the filtration method fall in the 0.1 to 50 µm range.

For the determination of lead in the larger or settleable particulates samples are collected by means of the standard dustfall procedure which requires a long sampling period, 30 days.

If information is needed relative to the distribution of lead among the different particle sizes special sampling devices are needed which can separate air-borne particulates into several fractions of different particle size range. Fractionating samplers are not in common use because of cost, low sampling rate and attendant complexity of operation and analysis of samples.

Organic lead (TEL, TML) may be trapped by passing pre-filtered ambient air through an absorbing train containing crystalline iodine or high purity activated carbon. Although the system is cumbersome, time consuming, and requires constant attention it performs adequately for the collection of gaseous lead compounds.

Analysis of Samples.

By suitable processing both the particulate and gaseous lead samples are converted into solutions of lead salts which may be analyzed by any one of several acceptable methods. The colorimetric Dithizone method, which has been the method of choice for many years, employs a lengthy and tedious procedure, but is very sensitive and gives excellent results. The use of atomic absorption spectrophotometry, a more recent development, has gained tremendous acceptance within the past five years. The high initial cost of instrumentation is offset by the simplicity and speed of analysis by this technique. Fully satisfactory results may be obtained by the application of this analytical technique. Equally satisfactory analytical results are obtained by use of emission spectrography or polarography, but these methods are not in common use at the present time.

Automatic Continuous Measurement of Atmospheric Lead

A recent report describes an instrumental method which may possibly permit the direct simultaneous measurement of gaseous and particulate lead on a continuous basis. Should this instrument possess the required sensitivity and be suitable for field use it will be an extremely useful tool in the elucidation of the lead-in-air situation.

ATMOSPHERIC LEAD MONITORING

Routine Monitoring of Particulates.

The National Air Surveillance Networks of NAPCA operates about 400 filter samplers in urban and nonurban areas throughout the U. S. for the collection of samples of air-borne particulate pollutants. Samples are collected over a 24 hour period every two weeks on a random schedule for a total of 26 samples per year. Practically all of these samples are analyzed for lead and fifteen other metals by emission spectrometry. It should be pointed out that a sampling frequency of 26 samples per year is not adequate to produce sufficiently accurate data to permit for an individual site the detection of year to year trends in lead or other pollutant concentrations. To provide sufficient data for trend analysis at least a four-fold increase in sampling frequency will be required. An increase of this magnitude will require a corresponding increase in supporting resources.

Many State and Local Air Pollution Control Agencies conduct particulate monitoring programs similar to NAPCA's. Some of the samples generated by these networks are analyzed for lead and the data contributed to the national data bank and many of those not analyzed can be made available to DAQED for analysis subject to available laboratory manpower.

The combined Federal - non-Federal effort provides for reasonably adequate definition of ambient lead concentrations for all cities over 50,000 population, many with less than 50,000 population plus a cross section of nonurban areas. Los Angeles and New York City conduct intensive particulate monitoring programs which include the measurement of lead.

Special Total Particulate Monitoring Programs.

Multi-City Studies.

In 1961[16] a 12-month study of ambient lead levels was made in Cincinnati, Los Angeles, and Philadelphia. This study was conducted with the support of:

American Petroleum Institute
Automobile Manufacturers Association
California State Department of Public Health
E. I. du Pont de Nemours and Company
Ethyl Corporation
Kettering Laboratory, University of Cincinnati
Public Health Service

ILZRO, API and [illegible]

A similar study supported by the same organizations in the same cities and four additional cities; Chicago, Houston, New York, and Washington will be completed by the end of 1971.

In the conduct of these studies from six to eight sampling stations are operated in each city at sites selected to provide a reasonable lead profile for each city. Also for each city insofar as possible a nearby community with a minimum of lead sources is selected to provide information on suburban background lead levels. Data from this study will help establish the intensity of monitoring required in urban areas to delineate population exposures to air-borne lead.

<u>Other Special Studies</u>.

A special two-month study of atmospheric lead has just been completed in Los Angeles County.

An intensive study is being conducted in New York City in an attempt to determine the correlation between traffic count, carbon monoxide and lead concentrations.

Research laboratories of the lead, automotive, petroleum, and fuel additive industries maintain a variety of studies related to the air pollution aspects of lead but results of these investigations are not always made available.

Monitoring of Organic Lead.

There is no organized routine monitoring program for the measurement of organic lead in ambient air at the present time. If any measurements are being made the work is probably being done by the industries.

Lead Concentrations in Ambient Air

The current method for assaying lead in samples of particulate pollutants does not distinguish between elemental lead, organic, and inorganic compounds of lead. Therefore, the proportions of lead from various sources, including possible naturally occurring amounts, cannot be positively identified. The effect of lead emissions from human activities can be clearly seen, however, by comparing concentrations at urban stations with those at nonurban stations, Table 4. Average lead concentrations at urban stations over the period 1966-1967 ranged from 0.1 $\mu g/m^3$ in Cheyenne, Wyoming to as much as 4 $\mu g/m^3$ in Phoenix, Scranton, and seven of the eight urban stations in California. In contrast, the range of averages at nonurban stations is approximately a power of 10 lower than at the urban sites. They range from 0.007 $\mu g/m^3$ at the White Pine County, Nevada station to 0.22 and 0.23 $\mu g/m^3$ respectively at the Clarion County, Pennsylvania, and Washington County, Rhode Island stations. The incursion of man's activities on the environment is further revealed when we examine lead levels at those nonurban stations whose locations are considered "remote", that is, the most distant from large urban centers. The last line in Table 4 shows this group of "remote" nonurban stations grouped at the lowest end of the nonurban concentration range. The implication is that the remaining nonurban stations are being perceptably influenced by surrounding urban areas and/or highway traffic. Since even the "remote" stations are located in Park areas where electricity is available and there is tourist traffic during at least some seasons, even these may owe some portion of the detected lead to man's activities.

Trends over the past ten years cannot be described because of a change in laboratory method beginning with 1966 samples. Variable influences on the relationship between the old and the new method are such that a conversion factor cannot be defined precisely enough to make the adjusted data a dependable basis for judging whether or not a trend has occurred. For the same reasons data from these years are not useful in examining for trends in the whole group of cities.

We do have two years of data by the new method, the calendar years 1966 and 1967. This is too short a period in which to judge a long term trend for an individual station because these measurements include a significant amount of inherent variability. However, if general lead levels in the nation are relatively stable the upward and downward fluctuations over the entire network should approximately balance. They do not. Seventy urban stations show data on lead concentrations in both 1966 and 1967. Six urban stations show no change from one year to the next, 18 show decreases, 46 show increases. See Figure 1. If we define a change of less than 0.3 $\mu g/m^3$ as not significant we have eight stations with decreases $\geq$ 0.3 $\mu g/m^3$, 27 with increases $\geq$ 0.3 $\mu g/m^3$.

The changes among 28 nonurban stations are also shown in Figure 1. The number of stations showing increases, decreases, and no change are very nearly equal, and only one station shows a change as large as 0.3 $\mu g/m^3$.

The implications of Figure 1 are that from 1966 to 1967 lead concentrations at the nonurban stations remained fairly stable while levels in the urban environments increased, on average. The increase in urban network average from 1.1 $\mu g/m^3$ in 1966 to 1.3 $\mu g/m^3$ in 1967 is statistically significant, but the data covers too short a period to give information about typical year-to-year variability, therefore no conclusions may be drawn about long term trends.

More extensive measurements of lead in three cities show variations with season of the year and with location in the city, and confirm the range of urban concentrations reported from the national network in Table 4. Table 5 shows seasonal averages for 4 locations in Cincinnati, 8 locations in Los Angeles, and 8 locations in Philadelphia. The highest seasonal lead concentrations typically occur in the fall and winter.

It has been claimed that alkyl lead compounds are quite toxic and easily absorbed by the body, however, only a limited data have been reported on ambient levels of these pollutants. Results obtained in a limited study conducted in Cincinnati are shown in Table 6. Lead alkyls may represent a significant portion of the lead in auto exhausts. Recent reports from Germany indicate that as much as 50 per-cent of total lead emitted may be in the form of organic lead compounds.

The concentrations of inorganic lead in Table 6 are noticeably higher than those reported for the general network. These were taken in heavy traffic. There can be little doubt that the use of leaded gasolines in internal combustion engines contributes significant amounts of lead to the atmosphere. Table 7 summarizes the results of several surveys for lead over a spectrum of locations. It is obvious that the closer one approaches a stream of traffic, and the more dense that traffic is, the higher the lead concentrations. Primary and secondary lead industries are also significant sources of lead but these are present in only a limited number of communities. The automobile pervades virtually all urban environments.

Size Distribution of Lead Particulates

Particles of greater than 5 um equivalent diameter are to a large extent trapped in the nasal and throat passages and consequently do not reach the lungs. Those less than 0.4 μm diameter are of the most concern because it is possible for them to reach the lower respiratory passages. It becomes, therefore, increasingly important to delineate the distribution of lead among the different sizes of particulate matter.

Sampling techniques are available for the collection of a variety of size ranges of air-borne particulates. The various techniques differ in their capabilities, sampling rates, and usefulness in defining the particle size distribution of lead. A recently developed sampler which is presently being field tested shows great promise of being capable of providing adequate samples of particulates in the desired size ranges. This will permit the determination of size distribution of lead particulates on a broader scale which heretofore has not been possible.

Data obtained in studies conducted to determine the size distribution of particulate lead indicate that most of the lead is associated with submicron particles. A study in Berkeley, California showed that 50 to 80 percent of atmospheric lead occurred in particles of less than 1 micron diameter; in Los Angeles 90 percent of the lead was found in particles smaller than 1.6 micron equivalent diameter.

Lee reported that particulate lead in Cincinnati had an average mass median diameter (MMD) in the 0.18 to 0.30 micron range while an average MMD of 0.74 micron was found in background air at a remote site a distance of 40 miles from Cincinnati. The average MMD of particulate lead ranged from 0.23 to 0.31 micron in samples collected by means of the Goetz aerosol spectrometer in Chicago, Cincinnati, Philadelphia, Los Angeles, Pasadena, Vernon, San Francisco, Cherokee, and Mojave in 1963.

Several studies have been conducted to estimate the size distribution of lead-associated particles emitted in automobile exhaust.

An early study by Hirschler indicated that emitted particles ranged in size from 0.01 micron to several millimeters in diameter. Particles smaller than 1 micron were by far the most numerous, but accounted for less than 5% of the emitted lead. Heavy particles, 5 microns and larger, which might be expected to settle rapidly, represented about 27% of the exhausted lead under city-type driving but increased to about 39% under acceleration. Mueller found that 62 to 80% of the lead particles from automobile exhaust were smaller than 2 micron diameter. Of these particles, more than 68% by weight were smaller than 0.3 micron.

In a recent study Lee found that about 95% of the total lead in automobile exhaust was associated with particles having aerodynamic diameters below 0.5 micron. A high ratio of water-soluble to water-insoluble lead in auto exhaust was found although ambient air measurements indicate that the proportion of water-soluble particulate lead amounts to only about 10 to 15% of the total lead sampled. The study shows also that 70% of the total lead in cooled, diluted automobile exhaust was water-soluble, whereas irradiation in the ultraviolet range increased the proportion of water-soluble lead to 85%.

Special short-time studies have been conducted by the Physics Branch, DCP, BEPS, NAPCA at various sites to gather additional information relative to the particle size distribution of lead. Use is made of the Cascade impactor and electrostatic fractionator. Further studies are planned for New York City.

From time to time particle size distribution studies have been carried out in the San Francisco Bay area. Ordinarily two fractions are obtained using a centrifugal separator but Cascade impactors are sometimes used. The Kettering Laboratory of the University of Cincinnati College of Medicine carries out intermittant particle size distribution measurements as part of a continuing lead study. Special short term studies are frequently conducted in the Los Angeles area by the University of California, Riverside, using the Lundgren impactor sampler. Standard Research Institute uses the Goetz aerosol spectrometer in special contract studies relating to atmospheric lead.

It is apparent that more work must be done to fully assess the health hazard associated with suspended lead aerosol. The NASN will institute a network early in 1970 to determine the size distribution of lead and other components in the air at six major urban areas utilizing the Andersen Cascade impactor modified by Lee and Flesch.

ADEQUACY OF CURRENT LEAD SURVEILLANCE PROGRAM

Total Suspended Particulates.

The combined Federal, State, and local particulate sampling programs provide a sufficient annual input of samples to provide for a reasonably adequate definition of the exposure to particulate lead of at least 90% of the urban population of the United States. Although total particulate lead data do not accurately define actual exposures to "respirable lead" a fairly accurate quantitative relationship can be established between total and respirable lead which for all practical purposes provides the requisite type of data. The greatest need in this area is for saturation type sampling in several selected major urban areas to fully establish the lead profile of these communities. Such an undertaking would require considerable additional resources on both the Federal and Local level.

Respirable Lead - Size Distribution of Lead.

This area is the most important of all and one in which the least work has been done. Lack of accomplishment has not resulted from lack of effort but because of the non-availability of adequate sampling technology and equipment. This deficiency has recently been resolved and sampling for particle size distribution will be initiated on a pilot scale at 6 - 8 stations by the end of 1970. Analysis of the samples collected in this project will go a long way towards defining the actual state in which particulate lead is found in the air and will better enable the potential health effects to be evaluated. Conduct of this sampling program requires much greater resources because of the cost of the sampling equipment and the complexity of the sampling and analysis procedure. However, when the results from such an investigation are fully evaluated the total cost would be reasonable. If the pilot study proves successful this program will be greatly expanded insofar as available resources permit.

Vaporous or Organic Lead.

There is very little, if any, activity in the measurement of TEL and TML which may be emitted from motor vehicles. Satisfactory sampling and analysis procedures are available but they are quite complicated, expensive, and require highly skilled scientists to carry them out properly. It is claimed that this form of lead represents 10% or less of the total and, therefore, isn't of consequence. Before such a conclusion can be drawn much additional data from many cities with differing traffic and pollution patterns must be obtained. To do this properly will require substantial manpower and funding.

However, the question of lead in air can never be fully resolved until adequate data on organic lead are collected.

Unusual Exposures to High Lead Concentrations.

Elsewhere in this report data have been presented showing exposure to lead of the commuter in heavy traffic. There is a need to gather further information on total exposures to include both organic and particulate lead. Considerable data have been collected relative to worker exposure in industrial atmospheres but there is very little information relative to exposures of street workers such as taxi and bus drivers, mailmen, traffic police, sidewalk merchants, workers in offices and stores near heavily travelled streets, and the like. Since, in many instances, these people are exposed for several hours each day to high ambient lead concentrations there is a need to fully define the magnitude of the problem by conducting extensive studies of what might be considered non-industrial occupational exposures.

Contributions of Primary and Secondary Lead Smelters.

A few primary lead smelters are located relatively close to metropolitan areas and many secondary smelters for recovery of lead from various sources are frequently located inside urban areas. The contributions of these smelters to the atmospheric lead burden have not been quantitatively defined. Therefore, it is not possible to delineate the extent of population exposures in these situations. A need exists for a full definition of any potentially hazardous situation resulting from smelting operations.

Inventories of Emissions of Lead in the Air.

It is essential that the location of non-automotive sources of lead be inventoried, and the chemical and physical nature and quantity of lead emitted into the air be documented. Further, such an inventory should be updated at regular intervals so that the latest emission data will be relatively current. Such an inventory is presently underway but its completeness will not be known until the final report has been published.

SUMMARY

1. The automobile is probably the major source of atmospheric lead both organic and inorganic.
2. Sampling methods for the collection of total particulate and organic lead are adequate but methodology for the collection of

different size ranges of particulates remain to be field evaluated before judgment can be rendered regarding adequacy.

3. Analytical methodology for the determination of lead in the collected samples is quite adequate. There is some hope that a continuous lead-in-air analyzer can be developed should the need be demonstrated.
4. Currently an estimated 95% of the population of the U. S. is being monitored for particulate matter which can be analyzed for lead. Samples collected under Federal auspices are routinely analyzed for lead; those collected by non-Federal agencies can usually be analyzed or made available to NAPCA for analysis. Unfortunately, the sampling frequency of 26 samples per year does not produce sufficiently accurate data to permit detection of trends. If it is essential that year-to-year trends be detected the sampling frequency will have to be increased many fold. Such an increase at the present time is not possible because of budgetary and manpower limitations. A substantial increase in resources will be required to support the sampling and analysis load imposed by an intensified lead surveillance program.
5. The sampling program to define the particle size distribution of

lead is in the experimental stage while a program for surveillance of organic lead is non-existant.

6. There is a need for an added effort to define exposures of people to the higher lead concentrations occurring on heavily travelled streets.
7. Additional data are needed relative to the contributions of non-automotive sources.
8. Complete lead emission inventories must be taken and kept current to show any changes in lead usage and emissions patterns.

TABLE 1

LEAD CONSUMPTION IN THE UNITED STATES

DURING 1967

USES	SHORT TONS	PERCENT
Storage batteries	466,665	37.0
Gasoline antiknock additives	247,170	19.6
Caulking lead	48,789	3.9
Pigments	103,190	8.2
Solder	68,833	5.5
Cable covering	63,037	5.0
Ammunition	78,766	6.3
Other	183,550	14.5
TOTAL	1,260,000	100.0

TABLE 2

CONCENTRATIONS OF LEAD IN THE IN-PLANT AIR
FROM A NUMBER OF OPERATIONS

INDUSTRY	OPERATION	Pb CONCENTRATION RANGE, mg/m^3
Storage battery manufacturing	Dumping & mixing	0.35-6.06
	Pasting department	0.21-5.31
	Drying	0.12-3.21
	All	0.04-39.0
Paint manufacturing	All	0.39-48.6
Insecticide manufacturing	Blending room	up to 8
	Packaging room	1 to 11
Non-ferrous foundries	Over cupolas	4.46-12.0
	Tapping area	2.0
	Furnace room	0.51-0.75
Painting & paint scraping	All	0.6-32
Riveting	Hot riveting	6.4-8.2
Smelters	Lead smelting	0.01-2.45
Glass manufacturing	All	up to 5.35

TABLE 3

CONSUMPTION OF LEAD IN ANTIKNOCK COMPOUNDS IN DOMESTIC MOTOR GASOLINE[a]

Year	Total lead metal, millions of pounds	Average lead content, g/gal
1953	234	2.28
1954	248	2.34
1955	276	2.37
1956	288	2.44
1957	282	2.38
1958	253	2.12
1959	258	2.06
1960	263	2.04
1961	256	1.98
1962	280	2.08

aSource: Ethyl Corporation and E. I. du Pont de Nemours and Company.

TABLE 4. DISTRIBUTION OF STATION-YEARS (1966-1967) AVERAGE LEAD CONCENTRATIONS ($\mu g/m^3$)

Station Location	No. of Stations		$\times 10^{-3}$			$\times 10^{-2}$			$\times 10^{-1}$			$\times 10^{-0}$		
			1.0-1.9	2.0-4.9	5.0-9.9	1.0-1.9	2.0-4.9	5.0-9.9	1.0-1.9	2.0-4.9	5.0-9.9	1.0-1.9	2.0-4.9	5. 9.
URBAN	132	# of Stations							1	10	53	59	9	
		Percentage							1	8	40	47	7	
ALL NONURBANS	31	# of Stations			1	8	6	7	7	2				
		Percentage			3	26	19	23	23	6				
REMOTE NON-URBANS	10	# of Stations			1	7		2						
		Percentage			10	70		20						

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Table 5. SEASONAL MEAN CONCENTRATIONS OF LEAD

June 1961 - May 1962, ($\mu g/m^3$)

	Site	Summer	Fall	Winter	Spring	Annual
Cincinnati	#30	1.6	2.0	1.7	1.6	1.7
	#31	1.1	1.5	1.0	1.0	1.1
	#32	1.5	2.4	1.5	1.7	1.8
	#33	1.1	0.8	1.0	0.8	0.9
All		1.3	1.7	1.3	1.3	1.4
Los Angeles	#1	2.0	3.0	3.6	2.1	2.7
	#2	2.0	4.1	4.0	2.0	3.0
	#3	2.3	3.4	3.7	1.7	2.8
	#4	2.4	2.3	2.6	2.3	2.4
	#5	2.0	1.9	2.1	2.2	2.1
	#6	1.2	1.6	1.9	1.5	1.5
	#7	1.4	2.5	3.3	2.0	2.3
	#8	2.2	3.3	3.6	2.6	2.9
All		1.9	2.8	3.1	2.1	2.5
Philadelphia	#10	1.4	1.7	1.8	1.2	1.5
	#11	1.2	1.6	1.7	1.1	1.4
	#12	1.3	1.9	2.3	1.6	1.8
	#13	2.7	3.8	3.8	2.9	3.3
	#14	1.8	2.3	2.6	2.0	2.2
	#15	1.0	1.4	1.3	0.9	1.1
	#16	0.8	1.0	1.0	0.7	0.9
	#17	0.9	1.1	0.9	0.6	0.9
All		1.4	1.9	1.9	1.4	1.6

Table 6. CONCENTRATIONS OF ALKYL LEAD VAPORS IN THE ATMOSPHERE IN HEAVY TRAFFIC IN THE CINCINNATI AREA

Sampling Procedure	Air Sampled, M^3	No. of Samples	Concentration of lead, $\mu g/m^3$ Alkyl lead Mean	Range	Inorganic Mean	Range
Iodine crystal (1g)	0.23	8	2.1	0.9-3.5	16.0	8.4-28
Iodine solution	1.2	15	1.1	0.4-2.4	11.1	2.5-19.5
Iodine crystal (20g)	2.1	3	0.2	0.1-0.2	15.5	1.3-23.5

TABLE 7. LEAD CONCENTRATIONS ON OR OFF ROADWAYS

Sampling Location	Range of Concentrations (ug/m^3) for Referenced Studies
Parked along road with low traffic density	1.9[1] - 2.0[1]
Parked along road with medium traffic density	4.6[2] - 4.8[2]
Parked along road with high traffic density	7.6[2] -38.0[2]
Driving in rural traffic	3.1[2] - 4.3[2]
Driving downtown rush hour	8.4[3] -15.3[2]
Driving commuter routes (not expressways) rush hour	2.4[3] -19.0[3]
Driving Expressway, rush hour	5.5[3] -25.3[2]

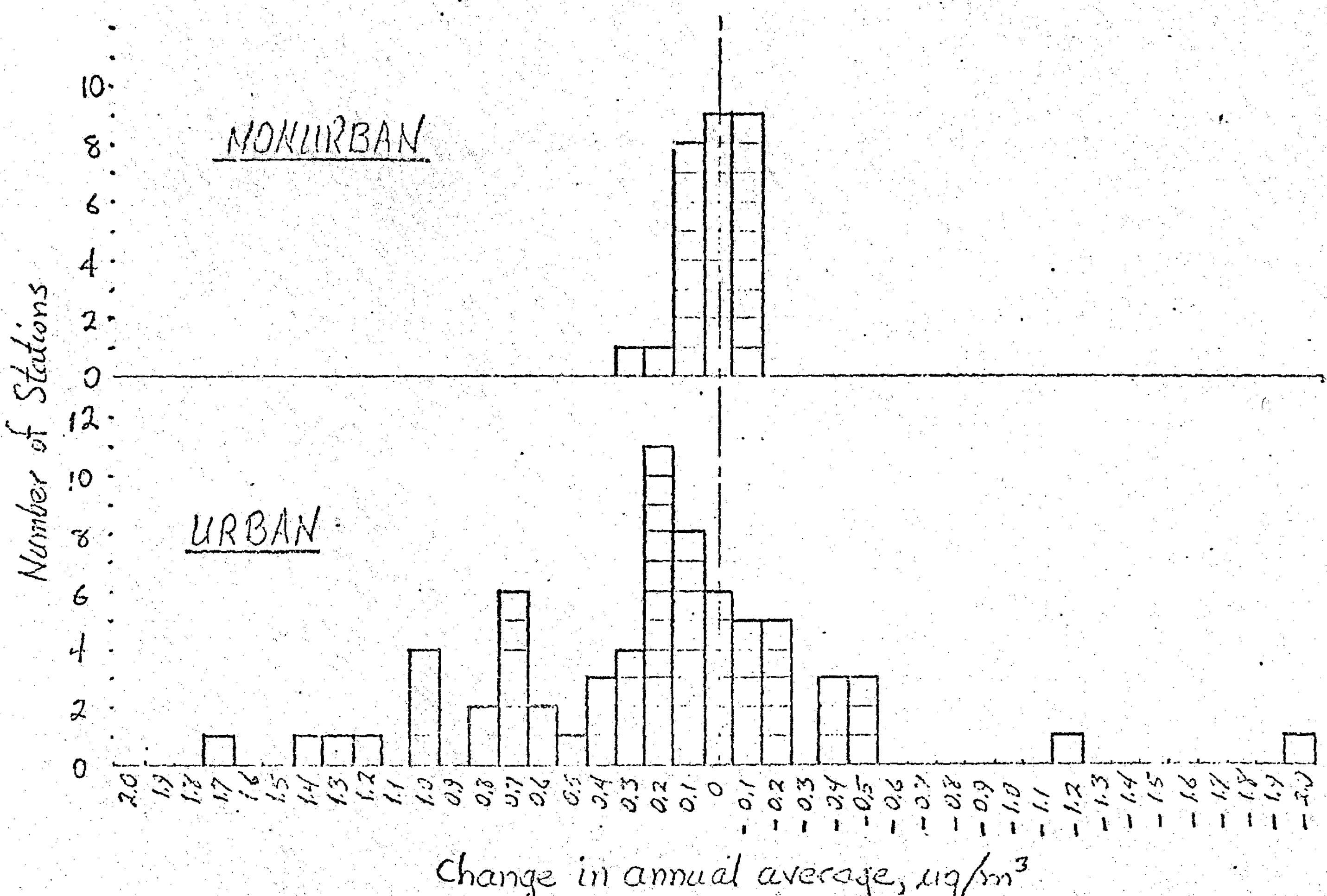

Figure 1. DISTRIBUTION OF CHANGES IN ANNUAL AVERAGE LEAD CONCENTRATIONS, 1966 to 1967.

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