BLOOD LEAD CONCENTRATIONS AND GASOLINE LEAD USAGE

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The use of lead in gasoline in the U.S. has been declining since 1970 (Slide 1). During the second National Health and Nutrition Examination Survey (NHANES II), carried out over the four year period, 1976-1980, an overall decline in mean blood lead levels of approximately 5.4 μg/dl, representing a 37% decline, was reported. These two items, decline in gasoline lead usage and decline in blood lead, were linked together resulting in the widely publicized claim that the decline in blood lead usage was solely caused by the reduction in gasoline lead usage (Slide 2).

This plot, which has been widely circulated and highly publicized, evidently had the scales adjusted to produce as near coincidence of the two time trends as possible. Statistical graphics have been used to emphasize the apparent association of the two time trends. As noted in the previous slide, any variable which has declined consistently or increased consistently since 1970 must be highly associated with U.S. lead in gasoline usage, but not necessarily caused by gasoline lead usage (Slide Off).

In the short time today, I would like to comment on the adequacy of the lead data used for time trends, discuss a major anomaly in the claim of declining blood lead being caused by declining gasoline lead usage, and note other declining lead exposures which could contribute to declining blood lead levels. The data on blood lead levels were obtained as part of the NHANES II survey. This survey was a cross sectional survey, designed to obtain health and nutrition data representative of the U.S. population for the mid point of the survey 1978.

Blood lead data in the NHANES survey were obtained for approximately 9700 individuals, ages six months to 74 years, black and white races, and there was a deliberate over-sampling of the young, old, and poor population segments. These population segments, the young, old, and poor were deliberately over sampled because of being of special interest for nutritional assessment. The survey, therefore, represents a "snapshot" of the U.S. population.

The exposure time for the snapshot was four years from February 1976 to February 1980. The study was not designed to look at population changes in time within the study, but to compare the study results with future study results. However, blood lead data have been used, (wrongly, I believe) to look at changes in time within the study. This obviously does not represent the optimum study design for time trends. An important consideration in evaluating time trends within the survey is that the sampling was carried out in 64 different locations and there was no repetitive sampling of individuals or of locations over the four year period. The sampling scheme introduced considerable bias, an example of which can be seen in the next slide (Slide 3) which shows the decline in the percent of urban residents during the survey period. This plot of the percent of urban residents in the sample gives a correlation coefficient with lead in blood similar to the correlation coefficient reported for lead in gasoline and lead in blood.

The same thing is illustrated in the next slide in which the % of children in the survey is shown to decline with time. These examples highlight the need to take into consideration changing demographics with time and show that the simplistic plot of mean blood lead and gasoline lead with time is misleading.

We and many others have carried out extensive analyses of the NHANES blood lead data. The data tapes are available, and I would urge others to examine the data. Unfortunately, the analyses have looked only at the change in gasoline lead and, not seriously at other declining lead exposures. This is because lead in gasoline was and is of political interest and because there are data readily available on lead in gasoline usage. However, a key problem, in the NHANES type analysis, even limited to lead in gasoline, is the necessity to obtain a meaningful exposure measure for each individual or at least for each of the 64 individual sampling sites. The next slide (Slide 5) lists possible measures of gasoline lead exposure. Ideally, one would like to have personal air lead sampler measurements for each of the 9700 individuals for which blood lead data exist. Of course, this is impossible. The next choice would be to have air lead data for each of the 64 sampling sites during the time period in which the population was sampled. These data were not available.

National gasoline lead usage has been used by some in their analyses, as a proxy for lead exposure, as was shown in the earlier slide of blood lead and gas lead usage. However, national gasoline lead usage has little relevance to the exposure at the 64 individual sampling sites. We chose the surrogates, population density and gasoline lead usage per area for each of the 64 sites. Certainly population density reflects exposure to automobile lead. The lead usage per area was not a good choice because it was dependent on the area of the state in which the sampling site was located. However, we are not aware that anyone has come up with any better surrogates of lead exposure for the individual NHANES sampling sites. Our analyses, as stated in the paper appearing in the proceedings, indicate that gasoline lead accounted for approximately 0.6 μg/dl of the reported 5.4 μg/dl decline in blood lead.

Many analyses of the NHANES data have been carried out and there will be many further analyses (Slide 6). However, forget about complicated statistical analyses and look at a simple comparison of the decline in blood lead in the rural population as compared to the decline in the urban population. The change in air lead in the urban areas, as shown by the U.S. EPA National Air Sampling Network from 1976 to 1980, was 0.5 $\mu g/m^3$ and in the non-urban (rural) areas, the decline was approximately 0.06 $\mu g/m^3$, a factor of 9. The change in blood lead over the NHANES study period, as given by the authors of the NHANES study, was greater in the rural area than in urban area. If lead in gasoline was the major or only cause of the decline in lead in blood, as some have claimed, then the decline in blood lead in the urban area should be much greater than the decline in the rural area. This anomaly is further illustrated in the next slide (Slide 7). Here the change in air lead and blood lead between the urban and rural areas for 1976 and 1980 are compared to the changes that occurred over time.

These data show that the changes in blood lead between the urban and rural populations, taken from the NHANES data, are 2.0 and 1.4 μg/dl in 1976 and 1980, respectively. This is consistent with other studies which have shown an urban rural gradient of 1-2 μg/dl in blood lead, and consistent with the data presented by Mr. Quinn of the U.K. this morning. While the ratios of the change in blood lead to air lead are somewhat high, the normal values are 1-2, they are at least somewhat plausible. The changes in blood lead with time, 1976 to 1980, which represent NHANES reported declines, clearly are out of line and reflect changes other than those resulting from gasoline lead usage. The large inconsistency between the rural and urban population for 1976 to 1980 is readily noticeable. This type of simple comparison shows, I believe, that factors other than declining lead from gasoline are influencing the decline in lead in blood. (Slide Off).

The question then follows, What factors other than the decline in gasoline lead usage could have contributed to the decline in blood lead during the period of the NHANES II survey? During this time, the National Academy of Sciences reported that there were 8 departments and agencies of the Federal Government carrying out programs to reduce human exposure to lead and there were 14 regulations in effect aimed at reducing exposure through air, water, food, eating utensils, and occupational exposures. I include occupational exposures because it is not widely known that the NHANES blood lead data did not exclude individuals occupationally exposed to lead.

The impact of one Federal program on a lead usage is shown in the next slide (Slide 8). This slide shows the declining use of lead solder in metal cans for food and shipping containers. From 1978 to 1980, lead used for solder for metal cans and shipping containers declined 42%. This was also the time period of the greatest decline in lead in blood. Based on this lead usage data, one could readily conclude that the decline in lead in solder usage is highly correlated with the decline in blood lead as shown by the NHANES data. The lead in solder figures come from the American Bureau of Metal Statistics. The declining use of lead in solder for canned foods is reflected in the Food and Drug Administration's reported declines in the lead content of canned foods for infants and adults as shown in the next two slides (Slide 9). These data, reported by FDA, show an approximate 50% reduction of lead in canned foods for infants over the period of the NHANES survey.

The next slide shows that FDA reports a 45% decline in the lead content of 13 popular adult canned foods from 1974 to 1980, plus 25-30% of canned foods were converted from lead soldered cans to welded cans. These reductions certainly are major. However, I do want to point out that the FDA market basket survey does not show a decline in total food lead over the NHANES survey period. It is difficult to reconcile why the market basket survey does not reflect the 50% reductions in lead in canned foods. This type of change, representing approximately 10% of total lead from food, should have been noted. The market basket survey reflects the diet of an 18 year old male in the late 1960's. Just because this particular diet does not reflect changes over the NHANES survey period does not mean that changes in lead intake, either by changes in dietary habits or dietary intake, could not have occurred. It is readily apparent that if declining lead in solder usage had been examined in the same manner as declining gasoline lead usage, the conclusion would be that the decline in blood lead resulted from the declining use of lead in solder. The contribution of the decline in lead in solder, however, cannot be denied as a factor in the decline of lead in blood. (Slide Off).

There are other programs with the aim of reducing lead exposure, many of which are difficult to actually quantitate. The effect of lead paint removal programs and public media educational programs aimed at the hazards of lead paint surely have had some impact. The ceramic industry has significantly improved the lead glazes used for everyday dinnerware. In the early 1970's, the industry was working to achieve a leaching rate of 7 ppm; however, through much research by the industry, the leaching rate has been reduced to less than 1 ppm. While these types of efforts are difficult to quantitate, they surely impact in reducing lead exposures.

Even the OSHA Occupational Standard for Pb could have contributed to reducing blood lead levels during the NHANES period. The standard came into effect during this period and significant reductions in blood lead exposure in the working population took place, plus there were added requirements which reduced the likelihood of lead being transported home to family members by shoes and clothing. Persons occupationally exposed to lead were not excluded from the NHANES survey. I do not know the number of persons occupationally exposed to lead in the sample involved because this information is not available. However, NHANES investigators have reported differences in blood lead in the population due to having jobs classified as being associated with lead exposure.

Studies in the U.K. have reported declines in lead in blood while lead gasoline usage has remained constant. Elwood reported a decline of 30% in blood lead between 1972 and 1982 while gasoline lead usage remained constant. Elwood stated that there had been a reduction in lead in food as reported by the Ministry of Agriculture, Fisheries, and Food and that mean dietary intake of many food stuffs had changed in the U.K.

In conclusion:

1. It should be recognized that the NHANES survey was not designed to look at time trends within the study, so it is certainly not an optimum design. There was no repetitive sampling of individuals or locations, and there were large differences in demographics among the individual sites which would result in lower blood lead levels at the end of the survey. These must be accounted for in an analysis.

2. The fact that blood lead declines were greater in the rural area than in the urban areas while air lead decline was 9 X greater in the urban area strongly confirms that factors in addition to lead in gasoline are contributing to the decline in blood lead levels.

3. The inference made by plotting decline in blood lead with decline in gasoline lead is misleading.

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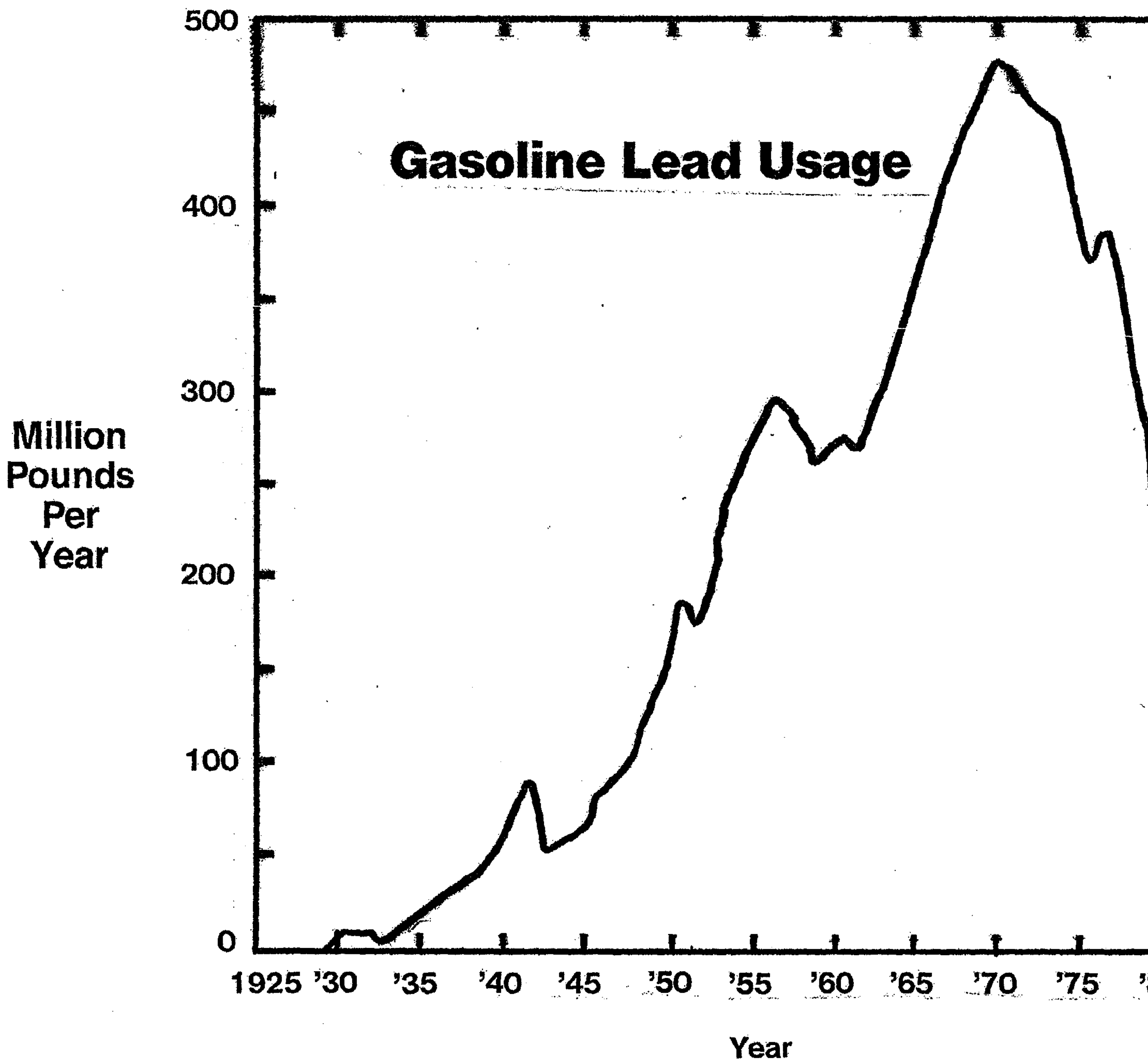

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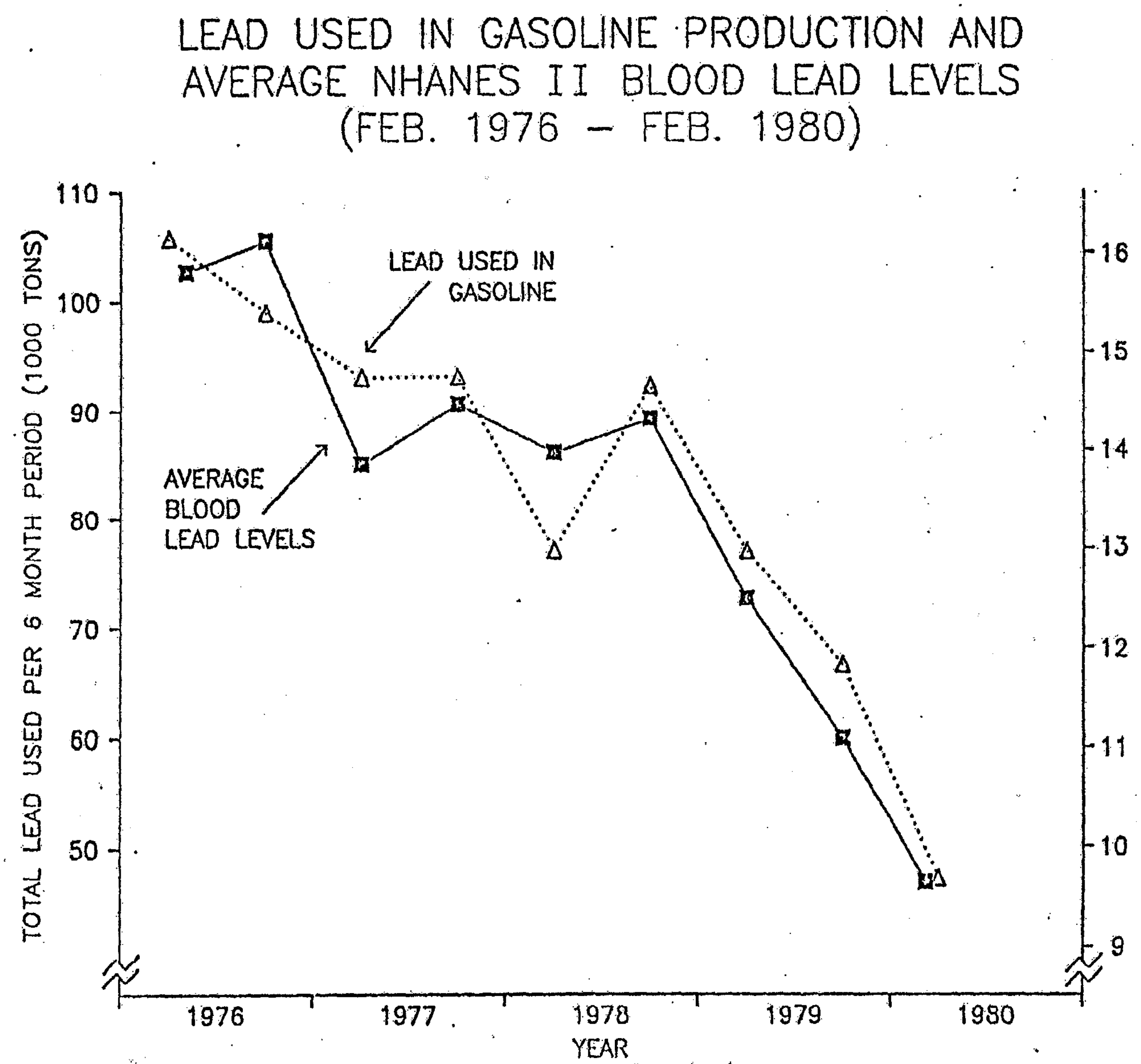

Figure 3. Original Houk Plot

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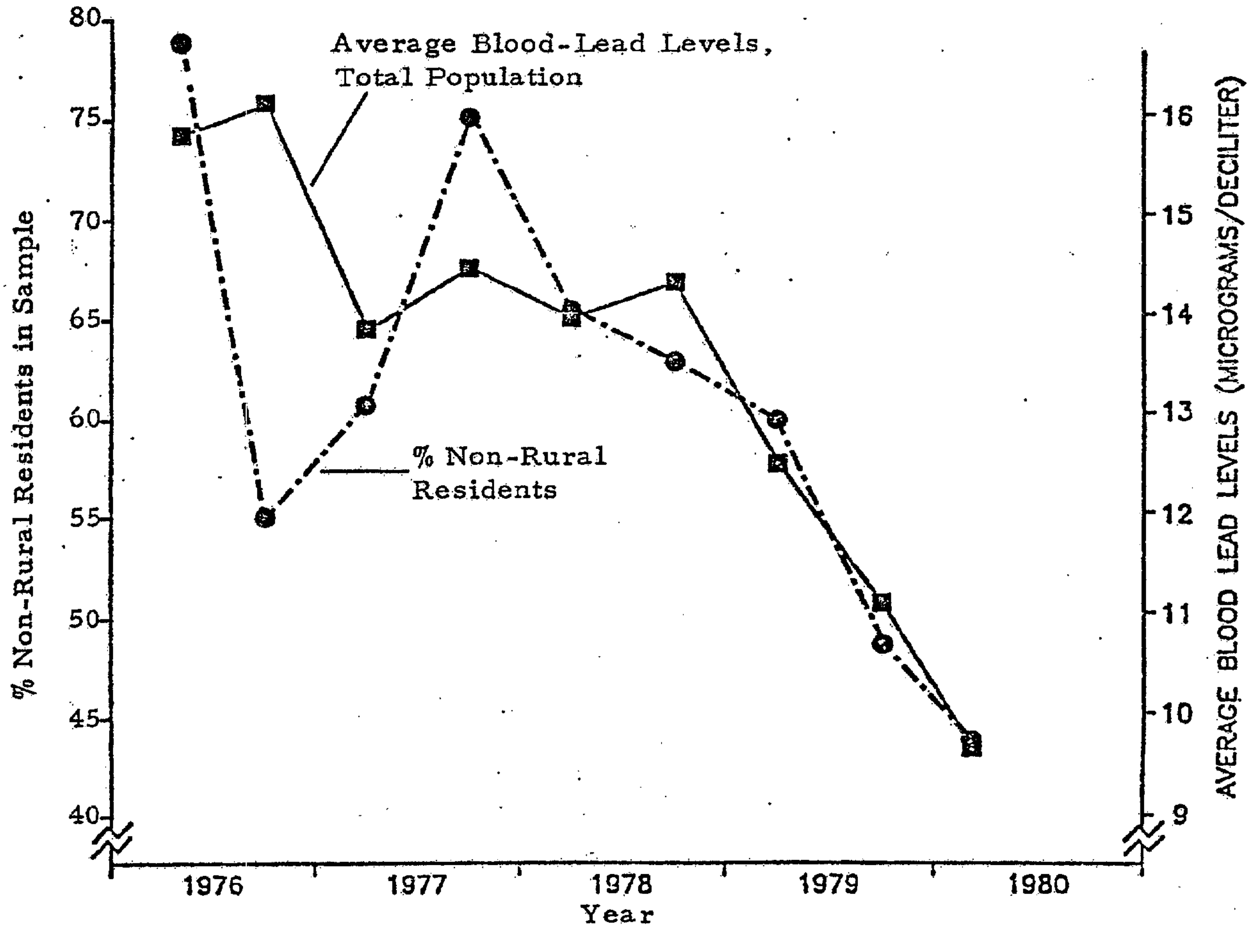

Figure 5. NHANES II Data

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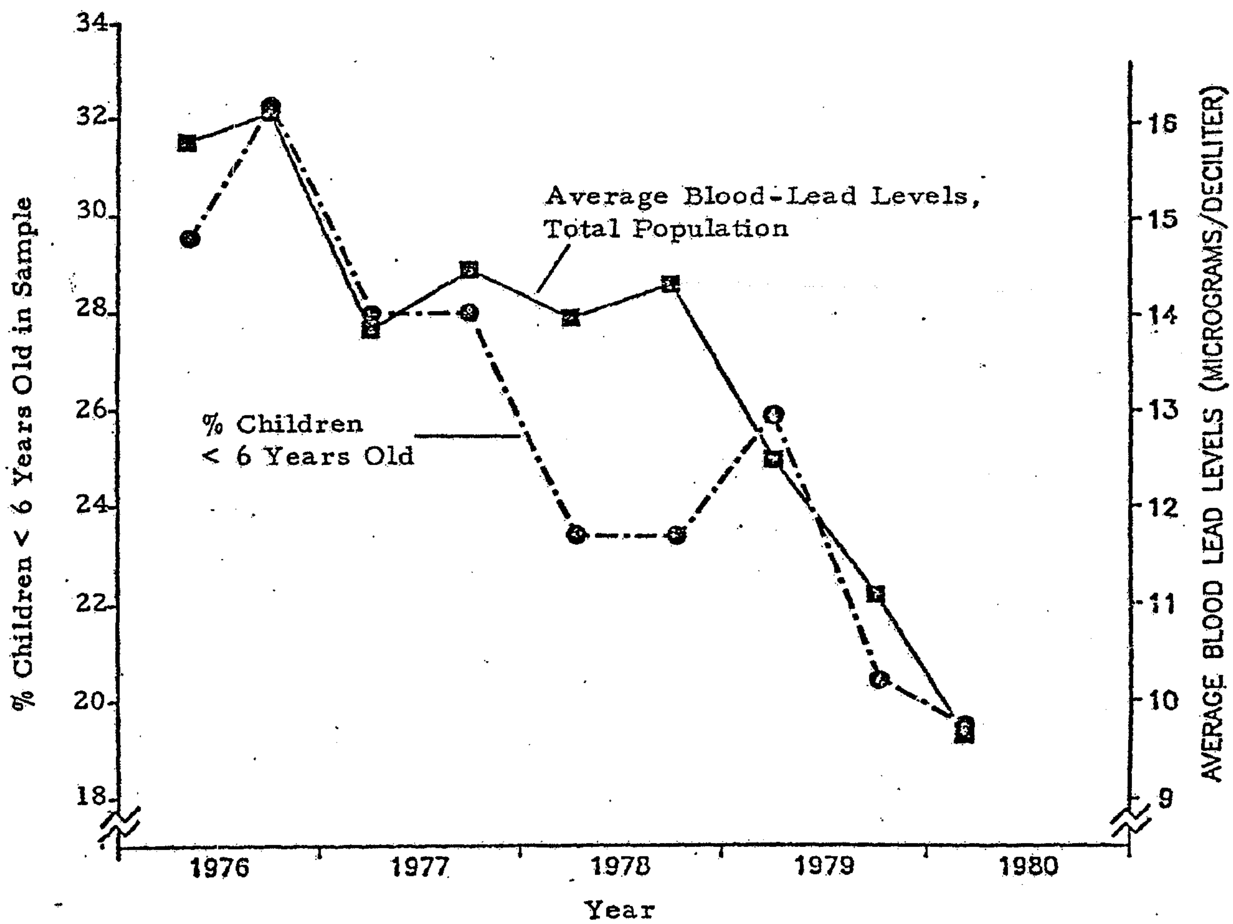

Figure 4. NHANES II Data

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POSSIBLE MEASURES OF GASOLINE LEAD EXPOSURE FOR 64 NHANES SITES

1. AIR LEAD SAMPLING DATA FOR EACH INDIVIDUAL—PERSONNEL SAMPLING—NOT AVAILABLE
2. AIR LEAD SAMPLING DATA FOR EACH OF 64 SITES—NOT AVAILABLE
3. SURROGATES FOR LEAD IN GASOLINE EXPOSURE:
   A. POPULATION OR POPULATION DENSITY FOR EACH OF 64 SITES
   B. GASOLINE LEAD USAGE PER AREA FOR EACH OF 64 SITES
4. GASOLINE LEAD USAGE FOR NATION FOR MONTHLY OR SIX MONTH PERIOD.

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MAJOR ANOMALY IN NHANES DATA

1. CHANGE IN AIR LEAD—1976 to 1980
   URBAN = 0.5 µg/m3
   NON-URBAN = 0.06 µg/m3
   CHANGE IN AIR LEAD IS 9 X GREATER IN URBAN AREA

2. CHANGE IN BLOOD LEAD—1976 to 1980
   URBAN > 250,000 POPULATION = 5.1 µg/dl
   RURAL = 5.6 µg/dl

3. CHANGE IN BLOOD LEAD GREATER IN RURAL AREAS THAN URBAN AREAS, ALTHOUGH DECLINE IN AIR LEAD IN RURAL AREAS IS ONLY 1/9 OF URBAN AREAS.
   URBAN—1 µg/m3 = 10 µg/dl
   RURAL—1 µg/m3 = 93 µg/dl

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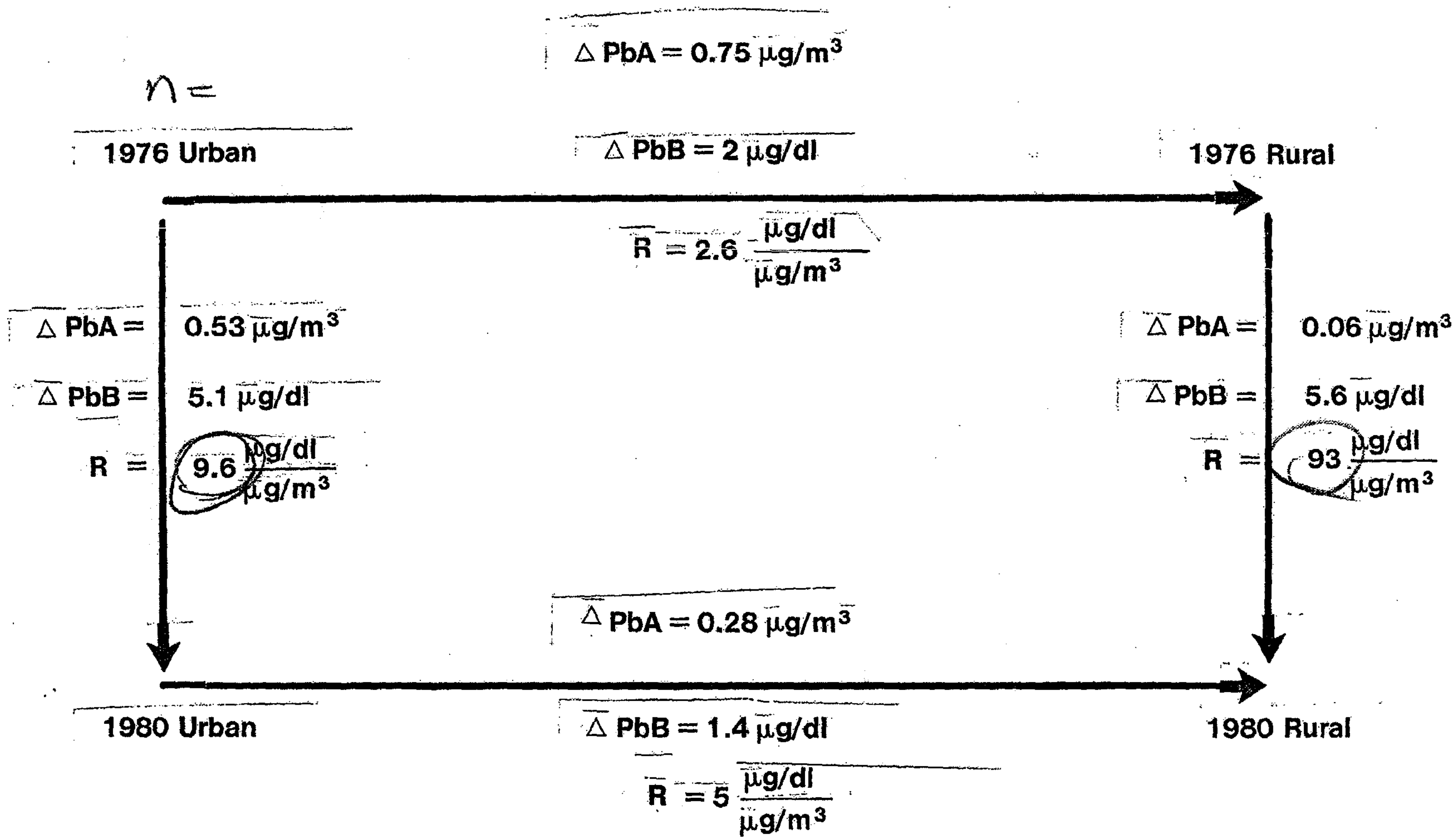
n =



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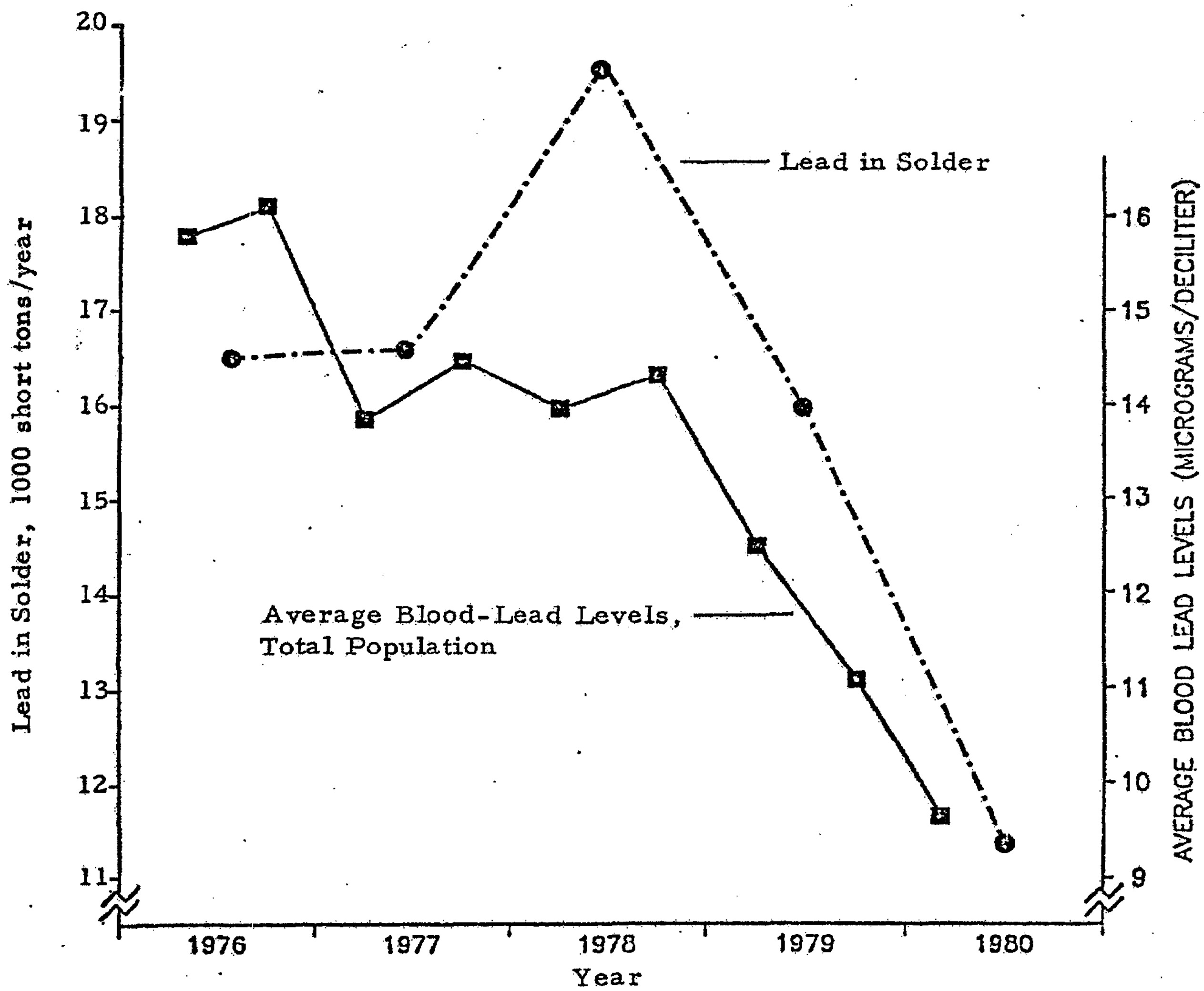

Figure 13. Lead in Solder and Blood Lead versus Time

LEAD IN FOODS—INFANTS

Product	Mean Pb Level, PPM		
	Early 1970's	1976-1977	1979-1980
Infant Formula, Concentrate	0.10	0.055	0.02
Infant Juices	0.30 [a]	0.045 [a]	0.015
Infant Foods Pureed [b]	0.15	0.05	0.03
Evaporated Milk	0.52	0.10	0.08

a—Packed in cans
b—Packed in glass

LEAD IN CANNED ADULT FOODS

	Mean Pb Level, PPM	
	1974	1980
13 Popular Canned Adult Foods	0.38	0.21

Plus 25-30% of Canned Foods Converted from Soldered to Welded Cans.