C-3561

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WILMINGTON, DELAWARE 19898

CHEMICALS AND PIGMENTS DEPARTMENT

May 15, 1990

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FROM: C. R. HUTTER CRH

ILZRO PAPER

Most of you are aware that ILZRO is preparing a position paper on lead antiknocks. An important part of this paper is the subject of health risks related to lead. A draft of the paper was sent to its sponsors in February 1990 and Gerard Pfeifer, Senior Research Associate, Ethyl Corporation Health and Environmental Department, has made numerous suggestions for improvements.

The proposed revision by Dr. Pfeifer for the section "Relationship Between Lead in Gasoline and Blood Level" is extracted from his general comments on the paper. Dr. Pfeifer was one of the invited guests at the March 16, 1990 seminar "The Health and Cancer Risks of Lead" which most of you attended.

Dr. Pfeifer has given me permission to circulate his comments. If you have questions or comments he can be reached on (504) 388-7565.

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B. Relationship Between Lead in Gasoline and Blood Lead

Blood lead levels in several countries have declined over the past several decades, whether or not gasoline lead usage decreased. Actions have been taken in many areas to control many sources of exposure to lead.

For instance, in the United States during the 1970's, 14 U.S. government regulations were enforced with the specific goal of reducing lead exposure from air, water, food, and non-food media. The U.S. Food and Drug Administration also initiated a program during this time which successfully reduced the lead content of a variety of foods. In 1981, Jelinek reported that lead levels in food for infants was only 10 to 20 percent as high as they were in 1972 because of technological changes in the infant food industry. Boyer and Johnson of the Food and Drug Administration (1982) reported that mean levels of lead in eight canned foods were reduced by 50 percent between 1974 and 1980. Other governmental and industry programs aimed at reducing lead in food and in a variety of consumer products have served to reduce lead exposure in the 70's and 80's.

A survey of blood lead levels reported in the literature shows an apparent decline in blood lead levels over the past several decades (Figure 6). This decline occurred even as gasoline lead usage was increasing rapidly. As can be seen in Figure 5, the rise in gasoline lead usage was particularly dramatic from about 1940 to 1970 as blood lead levels were declining.

Similar blood lead declines have been reported in the U.K. Oxley (1982) reported a 30% decline in blood lead levels in males presenting for pre-employment physicals at one plant between 1967-69 and 1978-80. The U.K. Department of the Environment reported a decrease of 4-5% per year from 1979 to 1986 (Quinn and Delves, 1989). Barltrop's group showed a progressive decrease in mean blood lead values in children from 20.7 ug/100 ml in 1973 (Barltrop et al., 1975) to 14.7 in 1977 (Strehlow and Barltrop, 1978) to 9.8 in 1980 (Strehlow and Barltrop, 1983). Elwood (1983) showed a decline of 30% in the blood-lead concentrations of women in Wales between 1972 and 1982. The amount of lead in gasoline used during this period remained relatively constant. Although lead concentration in gasoline declined somewhat over this period, the reduction was countered by an increase in petrol sales McInnes, 1987) (Barltrop, 1989). It is obvious, therefore, there was no relationship between the fall in blood lead levels in the U.K. and lead usage in gasoline.

Trends in blood lead levels were measured in Christ Church, New Zealand and environs by Hinten et al. (1986). Blood lead levels were monitored beginning in 1974 and showed a significant decrease from 1978 to 1985 in 2,830 subjects. In a population which had essentially no exposure to lead other than that from the general environment, blood lead levels fell in adult males and females greater than seventeen years of age by 42% and in school and pre-school children greater than nine months by 44% and 46% respectively. The investigators indicated that the decrease was not related to changes in laboratory performance, population sample selection or lead content in gasoline which remained at 0.84 g/l throughout this period. Rather the decrease seems to have occurred because lead had been eliminated or reduced in paint, toys, plastics, glazes and children's food cans.

There have been several studies specifically designed to evaluate the effect of changes in gasoline lead usage on blood lead levels in the general population. The first of these was carried out in Frankfurt, West Germany by Sinn (1980).

This study was designed to determine the effects of lowering allowable lead levels in gasoline from 0.4 g Pb/liter to 0.15 g Pb/liter on January 1, 1976. The city of Frankfurt was chosen as the site of study because (a) narrow, densely built-up areas with high traffic volume were available, and (b) there were few industrial emissions to cause interference. These criteria meant that virtually all the airborne lead was traffic-related and potential for maximum exposure existed.

Results of air monitoring showed a decline of about 30% in general air lead levels as a result of the lead phasedown. In the extreme case, 3 meters from the traffic, the decline was greater, about 70%. However, a decline in traffic density was also noted during the measurement period.

The blood lead data is somewhat harder to interpret because of interlaboratory differences in values reported by the three laboratories utilized in the study. (This points out the difficulties in accurately measuring blood-lead levels.) The decline in blood lead concentration reported for men ranged from 1.2-1.9 ug/dl, depending upon the laboratory. The results for women were more variable, ranging from 0.72-2.75 ug/dl. However, it appears that a decrease of over 60% in gasoline lead resulted in a decline in blood lead concentration of only about 10%. This should be taken as the maximum decline because no data were generated to show whether or not a general decrease in blood lead was occurring in Frankfurt during this period. As mentioned earlier, such a trend was occurring in the U.S. and the U.K.

The following important conclusions were reached by the author:

o Even though taxi drivers were considered the group most highly exposed to traffic lead, no statistically significant drop in blood lead was noted from 1975 to 1976 in this group. Such a decline was noted in results reported by 1 of the 3 laboratories participating in the study from 1976 to 1977, a year after the phasedown.

- The change in blood lead level due to a change in air lead levels will always be smaller than the theoretical maximum value for long-term exposure.

- Relatively high blood lead values would remain even if air lead values were zero. These levels would be about 80-90% of the pre-phasedown levels.

The U.K. Department of Environment (DOE) conducted a study to determine the effect of a phasedown of allowable lead levels in gasoline from 0.4 g/l to 0.15 g/l effective January 1, 1986, a reduction of over 60% in gasoline lead (Quinn and Delves, 1979). A total of over 2,000 blood samples were taken each year from 1984-1987. Population groups included (1) "exposed," adults living in houses fronting heavily trafficked urban roads, (2) "controls," adults living in areas with little exposure to gasoline lead emissions, (3) traffic policemen from several cities, and (4) children living in exposed areas.

While the air lead levels declined by about 50% as a result of the phasedown, blood lead levels were much less affected. Blood lead levels fell by about 10% in adults in the year preceding and the year following the phasedown. In addition, the change in blood lead was the same in the control population as in the exposed population. This rate of decline was not much different from that noted by the DOE from 1979 when they began monitoring blood lead levels. As groups, both the policemen and children had slightly greater declines the year after the phasedown than the year before. However, it should be noted that the mean blood leads in both these groups were lower than in the "exposed men" cohort.

The DOE concluded that:

"Exposure to lead from a number of sources was being reduced simultaneously; blood lead concentrations probably fell in both 1985 and in 1986 for reasons additional to the reduction in the lead content of petrol. For children, petrol lead appeared to have made a slightly larger contribution to the body burden than for adults."

Barltrop (Barltrop et al., 1989) initiated a similar long-term study to determine the effect of the January 1, 1986 phasedown on blood leads. Samples were taken in London (urban) and Suffolk (rural). These areas were equivalent to the DOE "exposed" and "control" groups. Blood lead was determined in 5 and 6 year old children and their mothers for three years before and two years after the phasedown of lead in gasoline. House dust and drinking water samples were obtained from all study participants and 3-day duplicated diets were collected twice a year from 25 mothers and 25 children in both the urban and rural areas. Lead in air, road dust, rainfall and house dust were monitored monthly at defined sites in each area. Umbilical cord blood leads were obtained from virtually every birth at a London maternity hospital during this time period.

A statistically significant decline in blood lead levels in mother and children occurred right after the phasedown of about 1.5 ug/dl in both London and Suffolk. Before the phasedown, the authors noted a significant decline in blood leads of about 1 ug/dl between 1983 and 1984 for London children seen in both those years, and a similar rise again in 1984 and 1985. This dip was not significant for London mothers, nor for mothers or children in Suffolk. No significant relationship was found between blood lead and dust lead concentrations in this study.

Lead in gasoline declined by over 60% after the phasedown and lead in air values declined by 50% in London in the first year and 40% in Suffolk. The delayed reduction in air lead concentrations observed in Suffolk are thought by the authors to be caused by: retention of stocks of higher lead petrol in the rural area into the post phasedown period; long distance transport of airborne lead from urban areas; and long-term retention in the atmosphere of a small fraction of atmospheric lead. It is noteworthy that the actual decline in blood lead levels in the rural area was about the same as in the urban area despite the fact that the air lead decline in the urban area was about 20 fold higher than in the rural area. The reason for this was not known by the investigators, but they suggested that routes of exposure other than direct inhalation of lead in air might be responsible.

Dietary and water intakes of lead were low and essentially equal in both urban and rural areas and appeared to decline during the study period. The authors noted that the decline in dust lead concentration was not as marked or as immediate as the decline in air lead concentrations. They suggest that some of the decline in blood lead levels between 1985 and 1986 could be due to a general trend downwards resulting from a decline in dietary intake. The authors stated that declining air lead concentrations must have had some influence on the decline in blood lead levels since the only consistent decline in blood lead levels in all groups studied was between 1985 and 1986 when lead in gasoline was reduced 63%. However, regression analyses on blood, air, house dust, and dietary data indicate that over 65% of the variance can be explained by dietary lead intake. Thus, the study indicates that dietary intake rather than air lead or dust lead is the major contributor to blood lead concentrations in the mother and children studied (Figure 7).

The Isotopic Lead Experiment initiated at Turin, Italy in 1974, examined the contribution of gasoline lead to total airborne lead in urban and rural areas; the contribution of gasoline lead to blood lead level in various population groups; and the pathway of gasoline lead to man through environmental compartments. The ratio of stable isotopes of lead 206 Pb and 207 Pb found in the Italian Piedmont was between 1.16 and 1.20. During 1975 to 1979, the investigators, through the Italian government, introduced lead into the Piedmont area from the Broken Hill mine in Australia. This lead had an isotopic ratio of 1.04. By measuring isotopic ratios of the lead content in various samples, the lower isotopic ratio Broken Hill lead could be traced through the population and the environment.

Three groups of subjects from the city of Turin and from the near and far countryside were examined to determine the percentage impact of gasoline lead on blood lead. The percentages were 26%, 17% and 14% respectively. It is important to note that these results cannot be extrapolated to other areas of the world without taking into account the following unique conditions in Turin:

- o the high lead content of gasoline
- o the very high air lead levels
- o relative background blood lead levels
- o the fact that blood leads were higher in the rural areas than in the urban area.

The content of lead in gasoline in Turin at the time of the study was 0.6 grams per liter or 2.4 g/gallon. This compares to Canadian usage at the same period of time of 1.0 g/gallon, U.S. usage of 1.5 g/gallon and 1.6 g/gallon in the U.K. Today, the usage levels have been decreased to below 0.1 g/gallon in these three countries. Thus, the contribution of gasoline lead to blood lead in Turin would be considerably larger than in Canada, the U.S. and the U.K. (Commission of the European Communities, 1983).

The air lead levels recorded in the Turin study were all considerably higher than past and current levels of lead in air in Canada, U.S. and the U.K. Air samples taken at urban sites in Turin ranged up to approximately 4 to 5 ug/m^3. Surveys of lead in air in Canadian, American, and British cities rarely exceed 1 ug/m^3.

Blood lead levels in Turin (22 ug/dl); near countryside (26.9 ug/dl); far countryside (29.6 ug/dl) tend to be considerably higher than those found in the U.S., U.K. and Canada. Also, in contrast to nearly all other studies, blood lead levels of residents of rural areas were higher than in the City of Turin. The data make it apparent that the Turin study reflects a unique situation and one that can only be extrapolated to other areas with extreme caution.

Two other studies also showed that gasoline lead was only a minor contributor to blood lead. The "Dallas Traffic Study" by Johnson (1978) found no relationship between traffic density and blood lead, even though lead in air (ranging from approximately 0.5 ug/m^3 to 1.9 ug/m^3) was positively correlated with traffic density. Yaffee (1983) used stable isotopic ratios of lead as a tracer. He determined that the blood isotopic ratios of children with moderately elevated blood lead levels (25 to 43 ug/dl) reflected the isotopic ratios of soil lead to which children were exposed. The soil lead isotopic ratios were very similar to samples contributing to blood lead levels, but were dissimilar from gasoline lead isotopic ratios, even though the children lived in inner city areas, or close to busy freeways.

Some researchers have attempted to relate gasoline lead to blood lead levels in samples collected for other purposes.

Billick (1979) used blood lead data from a New York City screening program designed specifically to identify children with high blood lead levels due to lead based paint exposure to develop a relationship between gasoline lead use and blood lead levels during the period 1971 to 1976. The report focussed on 170,000 records of pediatric blood lead levels in New York and described a fall during 1970-1976 of about 28% or almost 5% per year along with a concurrent fall in gasoline lead levels. Elwood (1986) has criticized the study because the children in the cohort came from both public and private health providers which were not representative samples of children and no assurance was given that the reasons for selection did not change over time.

Billick was also criticized (Ethyl Corporation, 1984) for computing quarterly gasoline lead use for the three states of New York, New Jersey and Connecticut rather than New York City usage and correlating the figures with quarterly blood lead levels of New York City children. It was pointed out that New York City had separate lead in gasoline restrictions, making the lead content of gasoline different in the city than in the tri-state area.

Annest et al. (1983) analyzed a chronological trend in data from the second National Health and Nutrition Examination Survey (NHANES II) in the United States which indicated a 37% drop in average blood lead levels (5.4 ug/dl) from February 1976 through February 1980. The investigators showed that this trend was strongly correlated with a reduction in the lead content of gasoline during this period. This study became very controversial since it was the pivotal point upon which the Environmental Protection Agency based its reduction of the lead in gasoline standard.

A special EPA-appointed review group pointed out several weaknesses in the study, including study design, but noted that "in the absence of scientifically plausible alternatives" the hypothesis that the drop in blood lead was caused by the drop in gasoline lead "must receive serious consideration." Other criticisms (DuPont 1984; Ethyl Corporation 1984) cited several other statistical errors in the analysis as well as inconsistencies in the data set. These include the fact that the cohort continually changed from a demographic standpoint over the four years of the study. One of the strongest criticisms was the failure of Annest, et al. to take into account other concurrent actions which could have reduced blood lead levels over the period of the study.

Therefore, while blood lead levels have declined over at least the past decade, these declines seem to have been for the most part, unrelated in a significant way to lead in gasoline usage. Other controls, such as on the lead content of food, have apparently been quite effective in reducing population blood lead levels.