Health Issues for Lead Workers and the General Population

1. Introduction

The health information content of this summary has been derived from Environmental Health Criteria 165: Inorganic Lead prepared by the International Program on Chemical Safety (IPCS) and published by the World Health Organization in 1995. Discussions of specific health issues are referenced by noting the pertinent page numbers of EHC 165. This summary is primarily focused upon health issues potentially relevant to the occupational health setting. Coverage is also provided of exposure and health issues which may be of concern to "informal worker sectors" involved in the use or recovery of lead-containing materials. Finally, a summary is provided of low-level exposure and health issues of potential relevance to the general population.

The health impacts of lead have been and are intensively studied. Multiple papers have appeared subsequent to the publication of EHC 165, particularly on matters of pediatric and general population exposure impacts.

2. Overview of Lead Exposure

Health effects of lead in humans are produced following exposure and uptake of lead into the body. The sampling of blood, preferably by venipuncture, and analysis for lead concentration is the most commonly applied index of exposure in both occupational and general population settings. Accordingly, discussions of health effects are generally related to the blood lead levels of the populations under study and not to levels of external exposure per se.

In the occupational setting, exposure via air and ingestion constitute the primary routes of exposure. Dermal absorption of inorganic lead through unabraded human skin is considered to be minimal (IPCS 165: 105). The relationship between air lead and blood lead in the occupational setting has been the subject of much study. In general, blood lead:air lead relationships are found to be curvilinear in nature. This is to say, the impact of a given air lead level upon blood lead will vary as a function of the intensity of exposure being experienced by the individual. In general, a given unit of lead in air will produce a greater increase of blood lead in an individual with a low blood lead level as opposed to one with a high blood lead level. Thus, estimates of the relationship between air lead and blood lead in the occupational setting suggest that there is an increase between 0.02 and 0.08 µg/dL (microgram per deciliter) of lead in blood for each µg/m3 (cubic meter) of lead in air (IPCS 165: 106).

The actual level of exposure experienced in the occupational setting will also vary as a function of industrial hygiene practices. Ingestion of lead via frequent hand to mouth activity and inadequate industrial hygiene, smoking, or eating in the workplace can all produce significant increases in blood lead. Thus, proper control of lead exposure in the workplace requires that adequate safeguards are maintained to properly limit inhalation exposure and that adequate industrial hygiene programs are in place to limit exposure through ingestion.

For non-occupationally exposed populations, blood lead levels are generally reflective of lead exposure from multiple environmental media. Once again, relationships between exposure level and subsequent blood lead levels in the general population

Generalizations can be made regarding the levels of lead in various environmental media and their impact upon general population blood lead levels. For example, an air lead level of 1 µg/m3 can be expected to directly contribute 1.92 µg/dL to the blood lead of the child. The same level of lead in air can be expected to contribute 1.64 µg/dL to the blood lead level of an adult (IPCS 165: 218). From a practical perspective, exposure to airborne lead will only be a major contributor to blood lead in areas of high air lead levels (IPCS 165: 107). General population blood lead levels are most often reflective of exposure via ingestion. Thus, lead contained within food, water, soil and dust are usually the most important determinants of blood lead. Dust and soil lead are particularly important contributors to the level of lead exposure experienced by a child (IPCS 165: 215).

The uptake of lead into the body will vary significantly as a function of the age of the exposed individual. Uptake of lead from the gastrointestinal tract in adults is usually limited to 5-10% of that which is swallowed. Uptake of lead can be modified by a variety of lifestyle habits. For example, lead ingested during periods of fasting is absorbed to a much greater extent than lead ingested with food (IPCS 165: 102).

The uptake of ingested lead into the body of children is generally higher than that for adults. For example, forty percent or more of ingested lead can be absorbed by a young child. However, the level of uptake is potentially modified, as in adults by dietary habits and the environmental medium which is being ingested. For example, ingestion of lead contaminated water under fasting conditions will produce greater uptake of lead than a comparable amount of lead consumed in food.

Children are also at greater risk of lead exposure by ingestion or mouthing of non-food items. Ingestion of soil and dust are generally not significant exposure vectors for non-occupationally exposed adults, but can be the principle source of exposure for children (IPCS 165: 103).

It follows that contamination of soil and dust from industrial processes will have a disproportionate impact upon the blood lead levels of children. As a generalization, environmental contamination of dust and soil at a level of one thousand parts per million has been estimated to contribute 1.8 µg/dL and 2.2 µg/dL, respectively, to the blood lead levels of children. However, this generalization must be regarded with caution due to the aforementioned curvilinear relationships which exist between lead exposure and blood lead levels, the effect of modifying factors such as dietary habits, and lifestyle factors which might alter the actual amount of soil in dust which are ingested by children. In some regions of the world, the historical use of lead based paint is a major source of exposure to lead.

3. Health Effects of Lead

Lead can adversely impact multiple organ systems and body functions. The effects of lead vary as a function of exposure intensity and duration of exposure. In addition, there is considerable interindividual variability with respect to susceptibility to lead toxicity. However, generalizations can be offered with respect to the lowest levels of lead exposure which are associated with specific health impacts. For the purpose of this discussion, acute (short-term) exposure impacts will be distinguished from chronic (long-term) exposure impacts.

Moreover, distinctions will be made between adults and children because of their differential susceptibility to lead toxicity.

4. Acute Exposure Impacts

Short-term high level exposure to lead producing blood lead levels greater than 70 µg/dL can have severe impacts upon the central nervous system (IPCS 165: 222). Acute lead exposures which produce blood lead levels in excess of 80 µg/dL can result in severe encephalopathy (convulsions) and/or coma. Blood lead levels as low as 70 µg/dL can produce these effects in children. The onset of severe acute symptoms can be associated with long term neurological damage and impairment of performance. Lethality can result if acute exposures are sufficiently high and/or prolonged. Acute lead intoxication can also have effects on other organ systems. Acute lead intoxication can also be associated with diminished kidney function at blood lead levels in excess of 70 µg/dL (IPCS 165: 192). High level exposure of pregnant women can induce abortions, but the dosimetry for this effect is poorly defined.

Severe symptoms of acute lead intoxication have been observed at the blood lead levels indicated above, but it should be recognized that significant interindividual variability exists and that such effects will not be produced at these doses in all individuals. Symptoms of acute lead intoxication more often manifest themselves as relatively non-specific symptoms of colic which include abdominal pain, constipation, cramps, nausea, vomiting, anorexia, weight loss and decreased appetite (IPCS 165: 202). Such non-specific symptoms have been observed in workers with blood lead levels in the range of 100-200 µg/dL and have been suggested to occur at exposure levels as low as 40 µg/dL. Colic-like symptoms in children are generally observed in the range of 60-100 µg/dL blood lead (IPCS 165: 203). Symptoms of colic are reversible and disappear when blood lead levels decline.

5. Health Effects of Chronic Lead Exposure

Long-term high level exposure to lead can be associated with adverse impacts upon a variety of organ systems and body functions. The following summary attempts to provide an overview of the principal long-term health effects associated with lead exposure and the blood lead levels required to produce these effects. This list is not meant to be exhaustive, but focuses upon effects of greatest clinical concern.

Central Nervous System

Impaired central nervous function and symptoms of colic can be observed in lead-exposed adults with a history of several years of exposure to lead of approximately 70 µg/dL. More sensitive neurobehavioral tests have observed subtle impacts upon central nervous function at blood lead levels of approximately 50 µg/dL. Sensory motor function is generally more sensitive than cognitive function with impacts being observed at blood lead levels as low as 40 µg/dL (IPCS 165: 222). Occupational exposure to lead has also been demonstrated to impact upon the conduction velocity of nerve impulses. The dose response for these effects remains to be accurately defined. Blood lead levels as low as 30 µg/dL may produce an impact upon nerve conduction velocity, but effects upon this endpoint are believed to be reversible as a function of the duration and level of exposure. This is to say, as exposure levels

Renal Function

Prolonged high level exposure to lead can produce clinically significant reductions in kidney function. This effect is generally believed to require prolonged exposure to lead at blood lead levels in excess of 62 µg/dL (IPCS 165: 226). Studies have observed subtle changes in renal function at lower blood lead levels, but the clinical significance of these findings remains to be determined.

Cancer

Administration of high levels of lead to rats and mice will result in the production of cancerous tumors of the kidney. However, evidence for the carcinogenicity of lead in inorganic lead compounds in humans is inadequate (IPCS 165: 227).

Immune System

There is no strong evidence in humans of an effect of lead on the immune system (IPCS 165: 227).

Anaemia

Lead is capable of interfering with multiple enzymes involved in the production of hemoglobin incorporated into the red blood cell. Exposure levels which produce significant decreases in hemoglobin production are generally on the order of 50 µg/dL. Children are somewhat more sensitive to this effect, with decreases in hemoglobin levels being observed at 40 µg/dL (IPCS 165: 221).

Prior to the onset of anaemia, a variety of biochemical alterations can be observed in the enzyme systems responsible for the production of hemoglobin. These enzyme alterations are often used as indicators of exposure, but are not generally regarded to be adverse health effects. An increase in erythrocyte protoporphyrin (hemoglobin molecules lacking iron) can be observed as a consequence of biochemical alterations in children at blood lead levels greater than 15-25 µg/dL and in adults at blood lead levels in excess of 25-30 µg/dL (IPCS 165: 219). As with altered enzyme activity, the production of erythrocyte protoporphyrin is most frequently used as an indicator of exposure.

Cardiovascular Effects

Acute lead intoxication has occasionally been associated with toxic effects upon the heart (IPCS 165: 200). Chronic lead exposure in the occupational setting does not appear to be associated with excess mortality due to ischaemic heart disease, cerebrovascular disease, or hypertensive diseases (IPCS 165: 202).

Numerous studies have been conducted of lead exposure and blood pressure at general population exposure levels. Interpretation of these studies has been complicated by the fact that numerous confounding factors impact upon blood pressure and lead exposure. However, the combined evidence demonstrates a very weak but statically significant association between blood lead levels and both systolic and diastolic blood pressure.

A doubling of blood lead levels appears to be associated with a 1 mm Hg increase in systolic blood pressure and a similar magnitude increase in diastolic blood pressure (IPCS 165: 227).

Although animal studies have provided plausible mechanisms for an effect of lead on blood pressure, the weak statistical associations observed human population monitoring studies are insufficient to demonstrate that low-level lead exposure is causally related to an increase in blood pressure. There is thus no clear evidence to suggest that lead has an impact of public health significance as regards hypertension or risk of cardiovascular disease (IPCS 165: 227).

Effects On Male Reproduction

Occupational lead exposure resulting in blood lead levels in excess of 40 µg/dL have been shown to effect sperm morphology and function. The reproductive consequences of these changes are unknown (IPCS 165: 226).

Effects On Female Reproduction

Historical studies have indicated that high level exposure to lead can have adverse effects upon pregnancy outcome in women. More recent studies have focused upon lower (less than 30 µg/dL) exposure levels. The results of more recent studies have generally been mixed and are insufficient to provide the basis of dose-effect relationships (IPCS 165: 204-205).

One study has suggested that the incidence of stillbirths and miscarriages is increased in women living in close proximity to a smelter. However, other studies have not observed this effect. Still other studies have suggested that lead exposure between 20 and 30 µg/dL will cause a decrease in the length of gestation. However, as with stillbirths, these observations have not been confirmed. Finally, one study has reported a significant reduction in birth weight associated with prenatal blood lead levels in excess of 15 µg/dL. However, other studies of comparable design and exposure level did not observe this effect (IPCS 165: 204-205).

Neurobehavioral Effects Upon Children

Numerous studies have been conducted to elucidate the effects of prenatal (exposure in utero) and post natal (exposure after birth) lead exposure upon child development. In general, prenatal/perinatal lead measures have been associated with delays in developmental indices at early ages. Associations between prenatal lead exposure (less than 30 µg/dL) and actual intellectual attainment at later ages have not been striking. Since most studies have not shown perinatal blood lead levels to be predictive of intellectual performance, most attention has been focused upon associations between postnatal lead exposure and child development (IPCS 165: 180).

A large number of studies have been conducted to determine the relationship between intellectual attainment and postnatal lead exposure. In most studies, a negative relationship is observed between lead exposure and IQ. This association is generally complicated by the presence of social disadvantage factors and other vari-

Thus, correction for these "confounding factors" generally reduces the strength of the association between lead exposure and IQ. After correction for these factors, most studies are consistent with a decrease in full scale IQ of two IQ points for a change of blood lead level from 10 to 20 µg/dL (IPCS 165: 190). Below this range, there is increased uncertainty regarding both the existence of an adverse association and the estimate of the magnitude of any association which might exist. The number of children included in most studies conducted to date with low blood lead levels, combined with the strong impacts of confounding variables and inherent limitations in the precision of the instruments used to detect effects, makes it extremely difficult to both detect effects and to estimate their magnitude. Similarly, it should be noted that recent estimates of the size of the effect of lead upon IQ have been derived from cohorts largely composed of individuals with blood leads less than 25 µg/dL. There is uncertainty as to whether the relationship between blood lead levels and IQ is the same at higher blood lead levels.

Finally, it is not possible to determine an age of critical susceptibility to lead exposure in the young child (IPCS 165: 225). Thus, it is not possible to determine the most sensitive age group for lead exposure with significant precision. Blood lead levels taken at age two and later correlate with intellectual outcome. However, given that blood lead levels also change as a function of age, this further complicates efforts to evaluate the dose response for lead's impact upon child development.

6. Summary Assessment of Relevant Health Issues

The toxic effects of lead have been subjected to adequate scrutiny so as to permit a determination of dose-effect relationships for a number of health endpoints and to establish the lowest observable adverse effect levels. Thus, for a number of health endpoints, dose response information is available to estimate the apparent threshold for clinical disease. The actual relevance of any of these endpoints to a given occupational setting will obviously be determined by the levels of exposure which occur.

Health endpoints for which lowest observable adverse effect levels appear to have been identified include encephalopathy, impaired central nervous system functioning, colic, renal disease, male reproductive function, and anaemia. Effects such as colic, anaemia and impaired male reproductive function are reversible when exposure is reduced.

Central nervous system function impacts in adults are often reversible, but permanent impairment can result if exposure is sufficiently intense and prolonged. The induction of renal insufficiency represents permanent damage.

Presently available data for other health endpoints suggest that they are not relevant for consideration of the adverse impacts which are associated with lead exposure. Included in this grouping are effects such as cancer, immune system impacts and cardiovascular disease. Finally, there are health effects for which concern exists but for which there is some uncertainty with respect to dose response. Effects upon female reproduction are an example of such an effect. High-level lead exposure can result in the termination of pregnancy, and some studies have suggested that blood lead levels below 30 µg/dL can impact upon parameters such as gestation period or

However, there is insufficient evidence to provide the basis for a dose-effect relationship on these endpoints.

The health endpoint that might be of greatest concern to general population exposure is the impact of postnatal lead exposure upon child intelligence. Dose-response information is available to estimate the size of the IQ impact above the range of 10 -15 µg/dL lead in blood. The existence and/or magnitude of effects below this exposure range is uncertain. Effects, once produced, are presumed to be irreversible.

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