CDC Advisory Committee on Childhood Lead Poisoning Prevention  
Lead and Pregnancy Work Group  
Subgroup 1 – Prevalence, Risk and Screening  
LITERATURE REVIEW  
October 3, 2005

This group would be asked to review literature including, but not limited to:
- Distribution of BLLs and other measures of lead body burden in –  
  o women of childbearing-age  
  o pregnant women at various gestational ages  
  o lactating women  
  o newborns  
- Risk factors/sources of lead exposure in pregnant and lactating women and the neonate.  
- Relationship between –  
  o maternal blood/bone lead levels and newborn blood lead levels  
  o pregnancy BLLs and postpartum BLLs?

Based on subgroup findings, this group would address the following questions:  
- Should pregnant women be screened for lead poisoning?  
  And, if so –  
  o Which pregnant women should be screened?  
  o When should screening of pregnant women occur?  
  o Are there questions that can predict which woman should be screened?  
  o What culturally sensitive interventions should be recommended to reduce exposure to potential sources?

Note:  
1) Subgroup 1 recognizes that this draft has limited review of literature related to occupational exposures in women and other current sources of lead exposure such as home renovations. These are being added.  
2) There is also overlap between Subgroup 1 and Subgroup 3 literature reviews that needs to be addressed.  
3) Articles published after 2002 are not included in this review, they will be added in Dec. 2005.

Introduction

Despite overall declines in population blood lead levels in both the U.S. (Pirkle et al., 1998) and Mexico (Rothenberg et al., 2000b), exposure to lead remains an international public health problem for at least three reasons.

First, toxic effects are being identified at lower levels of exposure. Research has emerged showing that fetal lead exposure has negative impacts on neurodevelopment and behavior at levels of exposure that remain widely encountered (references). Second, exposed subgroups exist and some, particularly children living in deteriorated housing (Lanphear et al., 1998), workers in several high-risk occupations (CDC, 2002), those living near hazardous wastes site or
active smelters (Garcia-Vargas et al., 2001), and residents in countries still using leaded gasoline (Albalak et al., 2003), may be highly exposed. Finally, lead stores previously thought to be inert are actually mobilized to a marked degree. There is concern that previously accumulated bone lead stores constitute an ongoing endogenous source of exposure. Because over ninety percent of lead in the adult human body is stored in bone (Barry & Mossman, 1970; Barry, 1975), the possibility exists for significant redistribution of cumulative lead stores from bone into blood during periods of heightened bone turnover (Roberts and Silbergeld, 1995). The long-term health effects of lead may be mediated by chronic exposure to accumulated lead stores in mineralized compartments that are released into circulation during periods of increased bone turnover and mineral loss (e.g. pregnancy, lactation, growth, hyperthyroidism, menopause, osteoporosis).

**DISTRIBUTION OF BLLS AND OTHER MEASURES OF LEAD BODY BURDEN**

**Women of Child-bearing Age**

There is increasing concern that unintended exposures to environmental contaminants may be adversely affecting maternal and infant health, including the ability to become pregnant, maintain a healthy pregnancy, and have a healthy baby. In the U.S., women of childbearing age represent approximately 45 percent of the total female population and at any given time almost nine percent are pregnant (Crocetti et al., 1990). Environmental risks may disproportionately affect women of child-bearing age and children because many of the exposures associated with social disparities have effects on reproduction and development (Silbergeld & Patrick, 2005). In fact, environmental contaminants have been documented in the blood (CDC, 2005), hair (CDC, 2005) and breast milk (Abadin, et al. 1997) of women in population studies with no known environmental or occupational exposures. INSERT NHANES PB RESULTS FOR WOMEN OF CHILD-BEARING AGE HERE. In addition, there are well-documented behavioral (geophagy or “pica”, use of folk medicines) and biological (bone mobilization, nutrient deficiencies) aspects of pregnancy that may intensify or increase likelihood of certain exposures, such as lead.

**Lead in pregnancy**

The dangers of high levels of lead in pregnancy have been recognized for centuries (Rom). Concern for ‘community-level’ and lifetime exposures are more recent. In 1969 Barltrop (1969) collected serial blood lead measurements from the first trimester throughout pregnancy and found no recognizable pattern. He showed that maternal blood lead concentration was highly correlated with umbilical cord lead suggesting the transplacental movement of lead to the fetus. There have been case reports of elevated blood lead measurements in pregnancy (Ryu et al., 1978; Mayer-Popken et al., 1986; Rothenberg et al., 1992). Thompson et al. (1985) documented a case of increased maternal and infant blood lead in a woman with a history of childhood lead poisoning, but no exposure during pregnancy or for thirty years prior. Manton (1985) reported a rise in his wife’s blood lead levels over the course of her pregnancy along with changes in the specific lead-isotopic ratios indicating that contributions to her blood lead during pregnancy did not correspond to an external source.

Most cross-sectional studies investigating blood lead levels during pregnancy have shown a tendency for blood lead levels to decrease at least through the first half of pregnancy.
Gershanik et al., 1974; Alexander and Delves, 1981; Bonithon-Kopp et al., 1986). Baghurst in the Port Pirie study found no difference in BLLs between different stages of pregnancy, weeks 14-20, 30-36 and delivery (Med J Aust 1987; 146:69-73). However, Fairas found BLLs were associated with gestational week of measurement, with levels declining after week 12 (Environ Health Perspective 1996; 104: 1070-1074).

Rothenberg et al. (1994), attempting to model kinetics over the course of pregnancy, showed a significant drop in blood lead levels from weeks 12 to 20. However, from 20 weeks to delivery they identified a significant increasing linear trend confirming the rise in blood lead levels in the later part of pregnancy. Schell et al. (2000) also reported changes in hematocrit-corrected blood lead levels over the course of pregnancy. Blood lead levels declined between the first and second trimesters and increased over the remaining course of pregnancy through delivery. Hertz-Picciotto et al. (2000) followed 195 women over the course of pregnancy and also found a U-shaped pattern of maternal blood lead concentration across pregnancy. The late pregnancy increases were steeper among women with low dietary calcium intake in both the low and high age groups.

Animal studies support the human data. Using stable lead isotopes in monkeys, researchers found a 29-56% decrease in bone lead mobilization in the first trimester was followed by an increase in the second and third trimesters (Franklin et al., 1997). The increases were up to 44% over baseline levels. Further analysis of maternal bone and fetal bone and tissues revealed that from 7-39% of lead in the fetal skeleton originated from maternal bone. Using Sprague-Dawley rats, Han and colleagues (2000) showed that fetal lead uptake was reduced in pups born to rats with higher dietary calcium intakes.

In a smelter area with stable or decreasing environmental exposures, increases in blood lead levels along with decreases in maternal calcium serum calcium levels during pregnancy were noted (Lagerkvist et al., 1996). By examining the lead isotopic ratio in a small number of pregnant women who were recent immigrants to Australia (and pregnant Australian controls), Gulson and colleagues (1997) were able to show that the changes in skeletal contribution to blood lead increased over pregnancy. In addition, the mobilization of lead from bone continued in the postpartum period for up to six months during lactation at levels higher than during pregnancy (Gulson et al., 1998b). Rothenberg et al. (2000a) followed over 300 Hispanic-American women with serial blood lead levels over the course of pregnancy and found that whole blood lead concentrations were significantly influenced by bone lead. Markowitz and Shen (2001) report a case of declining bone lead concentration in conjunction with an increase in blood lead levels over the course of pregnancy and early postpartum period. Maternal bone lead burden and breastfeeding practices and have been shown to be important predictors of maternal blood lead levels over the course of lactation (Tellez-Rojo, et al. 2002).

In Utero Exposure

Mobilization of maternal bone mineral stores during pregnancy and lactation has been suggested as a significant potential endogenous source of lead exposure to the fetus and neonate (Silbergeld, 1991). Generally, there is thought to be a low potential for transfer of lead when maternal exposure levels are low. However, since it is estimated that up to five percent or more of bone mass may be mobilized (Hayslip et al., 1989; Sowers, 1996), the possibility exists for significant redistribution of cumulative lead stores from bone into plasma, and subsequently into...
breast milk, during periods of heightened bone turnover (e.g., pregnancy and lactation) (Figure I-2.).

The contribution of lead mobilized from bone to plasma may not be adequately reflected by whole blood lead levels (Cake et al., 1996). Plasma is the main biologically active compartment from which lead is available to cross cell membranes (Cavalleri et al., 1978). Recent data suggests that the plasma-to-whole blood lead ratio can vary quite widely among and within individuals. Cake et al. (1996) demonstrated that serum lead varied from 0.8-2.5% of whole blood lead and serum lead tended to be a higher proportion of whole blood lead when bone lead, particularly calcaneus (trabecular bone) lead, was also high. Although whole blood lead levels are highly correlated with plasma lead levels, lead levels in bone (particularly trabecular bone) exert an additional independent influence on plasma lead levels (Hernández-Avila et al., 1998b). This provides further evidence for the hypothesis that mobilized bone lead stores pose a significant threat to fetal development in a way that is not adequately reflected by measuring blood lead levels.

Cord Blood Lead Levels

Umbilical cord blood lead at delivery has been widely used as a measure of fetal exposure (Scanlon, 1971). Maternal blood lead concentration is highly correlated with umbilical cord lead suggesting the transplacental movement of lead to the fetus (Hernandez-Avila et al., 1997). Indeed, lead freely crosses cell membranes, including the placenta, by passive diffusion (Goyer, 1996; 1990) and levels of lead in maternal blood during pregnancy provide information about in utero exposure to the fetus (Graziano, 1990). Harville et al. (2005) studied factors influencing the difference between maternal and cord blood lead and showed that high blood pressure and alcohol consumption were associated with higher cord lead relative to the lead of the mother. In a 1979-81 longitudinal study of blood lead levels in 249 newborns in Boston, Rabinowitz et al. (39—Rabinowitz, 1985) found an overall mean blood lead level of 7.2 mcg/dL. Shen XM et al (1997) found that of 348 umbilical cord samples in an urban area of Shanghai, 142 babies (41%) had BLLs >=10. The study also found that previous history of maternal smoking, >=1 family member occupationally involved with lead, proximity to a major traffic way, household coal combustion, neighborhood coal combustion, lower SES and eating pidan during pregnancy were risk factors for elevated cord BL.

Lead Exposure and Lactation

There is indirect evidence that breast feeding may expose infants to lead in that as lactation duration or the number of breast feeding intervals increase, bone lead levels decrease suggesting that as bone is mobilized to meet calcium needs during lactation and this bone is subsequently replaced with new bone with lower lead levels. In 101 suburban residents where K-XRF tibial bone Pb and BPb were measured having ever nursed was inversely related to bone lead levels. In a pilot study using a cross-sectional, convenience sample of 24 rural Mexican women, Moline et al. (36—Moline, 2000) found a significant inverse relationship between months of lactation and age-adjusted calcaneus lead level. In a cross-sectional pilot study of blood (and bone) lead levels among 98 recently postpartum women in Mexico city, Hernandez Avila et al. (23—Hernandez Avila, 1996) found that significant predictors of higher blood lead
levels included higher levels of lead in patella bone (but not tibia). A 34 mcg/g increase in patella lead was associated with an in 2.4 mcg/dL increase in blood lead. The study suggests that patella bone is a significant contributor of blood lead during lactation.

**RISK FACTORS/SOURCES FOR ELEVATED BLLS IN PREGNANT AND LACTATING WOMEN AND THE NEONATE**

A large body of research suggest that women with specific risk factors or exposure sources have blood lead levels that could adversely affect their ability to become pregnant, maintain a pregnancy and give birth to a healthy child.

1. **Women who live near a point source of lead**

   Women who live near lead mines and smelters are often exposed to high levels of lead contamination. Baghurst et al, in 1979-1982, prospectively evaluated factors that influence blood lead levels (BLLs) in women living in Port Pirie, South Australia. Port Pirie is the site of a large lead smelter. Geometric mean BLLs were elevated 40-50% in women living in the town versus women in farms outside town and there was a strong association between mean antenatal BLLs and soil lead (soil lead concentrations being lower on outskirts of town and beyond). (Med J Aust 1987; 146:69-73) BLL was also increased if women lived in Port Pirie > 3 years, were of lower socioeconomic status, and age < 21 years.

2. **Women who live in or are recent immigrants from an area where ambient lead contamination is high.**

   Women in developing countries are exposed to a number of lead sources in their environments including lead in gasoline. In areas where background levels of lead are high primarily, blood lead levels will decrease as the exposure is controlled or eliminated but the effects of lead exposure may persist.

   Brown et al, investigated determinants of bone and blood lead concentrations in women in Mexico City during the early postpartum period. This was a retrospective analysis of data from an earlier study on calcium supplementation, carried out in 1994-1995. Behaviors and health factors affecting BLL are discussed under other categories below, but age and time living in Mexico City were also strong predictors of tibial and patellar lead. % life lived in Mexico City was strongly related to bone lead and in final model of BLL, patella lead (trabecular bone with shorter turn over time) explained a third of the variance in BLL (Occup Environ Med 2000; 57:535-541).

   BLLs were found to be higher during fall and winter and lower during spring and summer, by Farias et al, who prospectively examined determinants of BLL in pregnant women of high and low socio-economic status in Mexico City in 1994-1995. This was attributed to fact that winter is dry in Mexico City and summer is wet, with also reduced traffic. Regression models indicated that a main determinant of BLL was season of BLL sampling in women from private hospitals. In the Farias study there was no association seen between BLLs and location of house near traffic, or nearby industries (Environ Health Perspective 1996; 104: 1070-1074).

   In a study of blood, urine and food intake lead levels in women in the general population (not pregnant or lactating) in East and Southeast Asia Ikeda et al. (30---Ikeda, 2000) found that lead in the atmospheric air explained most variance among Asian women.
In a 1979-81 longitudinal study of blood lead levels in 249 newborns in Boston, Rabinowitz et al. (39—Rabinowitz, 1985) found an overall mean blood lead level of 7.2 mcg/dL. The newborns BLLs were significantly correlated with amount of lead in dust, soil and paint and refinishing activity. Water lead, nearby traffic, dust weight, race, maternal age and education, and sex were not predictive of blood lead levels.

Rothenberg et al (1996) studied Mexican women of low to middle SES from 12 weeks of pregnancy to delivery to determine factors that explain the relationship between cord BL and maternal BL. They found from 245 paired maternal-cord BL samples that age, use of lead-glazed pottery and canned foods was associated with increased cord blood lead.

Falk described international childhood lead exposures in association with milling of flour using stones that have lead parts, use of ceramic ware, contact with batteries, mining and smelting, and persistence of leaded gasoline (Pediatrics 2003; 112: 259-264.)

**We may not need this study.** In a 1997 survey, for 16 of 18 Latin American and 2 out of 10 Caribbean countries responding lead in gasoline remained a major problem, although phase out of leaded gasoline was expected to be completed throughout the region by 2005 (Walsh Carlines, 2001) The impact of leaded fuel is more important in urban settings, given their higher vehicular density. Seventy five percent of the population of the region lives in urban areas, and children younger then 15 years of age, the most susceptible group, comprise 30% of the population. Other sources of lead exposure identified in the region included industrial emissions, battery recycling, paint and varnishes, and contaminated food and water. Lead exposure in women or pregnant women was not discussed in the article.

### 3. Women with specific lifestyle/health behaviors

Antenatal life style variables that might affect maternal and infant cord BLLs were evaluated by Ernhart et al. in Cleveland in 1981-1982. Regression analysis indicated that alcohol exposure (in ounces per day) and smoke exposure (by history and blood thiocyanate) contributed appreciable and independently to maternal and cord blood lead levels. Cord hematocrit also correlated with infant cord blood level of lead. (Environ Res 1985; 38; 54-66)

In Baghurst study, BLL was also increased in pregnant women not on iron or folate supplements, or if they were a smoker. (Med J Aust 1987; 146:69-73)

Symanski found that heavy smoking, defined as smoking ****, contributed 1.7 µg/dL of lead to the blood lead levels of pregnant women.

In the Farias study there was no association seen between BLLs and alcohol use, smoking, use of canned food, use of coffee or soda. (Environ Health Perspective 1996; 104: 1070-1074) **Note: there may be quality issues with this study.**
In a large cohort of Mexican women (not all followed throughout), factors associated with increased BPb at particular times were: dietary canned foods, soft drinks, coffee drinking, residence in Mexico City, and use of indigenous pottery. Gravidity (and # of abortions) and dietary calcium (milk) were associated with a decreased BPb.  

Rothenberg 1994

In 101 suburban residents K-XRF tibial bone Pb and BPb were measured. Predictors for high bone Pb were age, sex, and pack-years of smoking. No prevalence data. Kosnett 1994

24 maternal aged women studied by K-XRF at calcaneus patellar and tibia sites. Calcaneus Pb, but not patellar (also a trabecular bone) and not cortical bone, increased with age. Greater body mass and smoking were associated with increased cortical bone Pb. BPb associated with lead-glazed ceramic use. No prevalence data. Moline 2000

In a cohort study of blood lead levels in all trimesters of pregnancy among 195 healthy women in Pennsylvania, Hertz-Picciotto et al. (25-Hertz-Picciotto, 2000) found that blood lead levels in pregnancy increases with age, smoking, lower educational level and African American race.

In a study conducted between 1979 and 1981, umbilical cord blood lead samples were taken from 4,354 women at delivery in the Boston area. Interviews and medical records were reviewed. The following variables were found to be significantly associated with elevated blood lead: tobacco use, alcohol use, coffee use, tea use, marijuana use, having had an abortion, receiving welfare, being unmarried, being black, and being Hispanic (Rabinowitz and Needleman, 1984).

Recknor et al conducted a retrospective study of 200 mostly black infants (ages 6-22 mo) from Charleston County, South Carolina to determine the relationship b/w prenatal care of the mothers and BLLs of the infants found with each decreasing level of prenatal care (defined by the Modified Kessner Index), there was an increased risk of having an EBLL (Recknor et. al. 1997).

Rhainds and Levallois conducted a retrospective analysis from 1990 survey data from two Quebec, Canada hospitals among 430 mothers and their newborns to evaluate the effect of cigarette smoking and alcohol consumption during pregnancy on cord BLLs. In multivariate analysis both cigarette smoking, an average increase of about 15% in cord BLLs was estimated for every 10 cigarettes smoked per day and alcohol intake, mean BLLs in babies whose mothers didn’t smoke during pregnancy but who drank alcohol moderately was 17% higher than those of nonsmoking mothers who did not drink, made significant and independent contributions to cord BL concentrations (Rhainds and Levallois, 1997).

Schell et al (2003) conducted a study of 220 mother–infant pairs from lower SES living in Albany County, New York to determine the influences of maternal diet and nutrition during pregnancy on the BLL of neonates. As expected, Maternal BLLs were strongly and positively related to neonatal BLLs. Among the anthropometric measures of maternal nutritional status, variables measuring gain in weight and arm circumference were negatively related to neonatal BLLs. In multivariable models reflecting different analytic strategies and including maternal BLLs, anthropometry, and sociodemographic characteristics, dietary intakes of iron and vitamin D were negatively related to NBPb. The effect of zinc varied substantially depending on model
covariates. Effects of dietary constituents are difficult to distinguish, given the intercorrelated nature of nutrients in the diet. Nevertheless, higher iron, and vitamin D intake were associated with lower neonatal lead levels. [Environmental Health Perspectives • VOLUME 111 NUMBER 2 February 2003]

4. Factors which may (or may not) protect [This is the section with most overlap with subgroup 3]

In the study by Farias in Mexico City, regression models indicated that in women whose diets were deficient in calcium, taking calcium supplements lowered BLLs about 7 micrograms per dL. (Environ Health Perspective 1996; 104: 1070-1074)

In Baghurst study, higher BLL was found if there was lower calcium in diet but no difference noted with use of calcium supplements (for most women calcium intake already high). (Med J Aust 1987; 146:69-73)

In study by Brown, on determinants of bone and blood lead, women with calcium intake in second quartile (830-1007 g/day) had higher BLLs than women in other quartiles. This finding was of borderline statistical significance (p<0.10) (Occup Environ Med 2000; 57:535-541)

In a cross sectional pilot study of blood (and bone) lead levels among 98 recently postpartum women in Mexico city, Hernandez Avila et al. (Hernandez Avila, 1996) suggested that consumption of high calcium content foods may protect against the accumulation of lead in bone.

Rothenberg 1994 found gravidity (and # of abortions) and dietary calcium (milk) were associated with a decreased BPb.

In a cohort study of blood lead levels in all trimesters of pregnancy among 195 healthy women in Pennsylvania, Hertz-Picciotto et al. (Hertz-Picciotto, 2000) found blood lead levels decreased with a history of breast feeding and higher intake of calcium.

Umbilical cord blood lead samples were taken from 4,354 women at delivery in the Boston area. Interviews and medical records were reviewed. The following variables were found to be significantly associated with low blood lead: being college educated, being Jewish, being younger and being multiparous (Rabinowitz and Needleman, 1984).

Rothenberg et al (1996) studied Mexican women of low to middle SES from 12 weeks of pregnancy to delivery to determine factors that explain the relationship between cord BL and maternal BL. They found from 245 paired maternal-cord BL samples that mother with occasional alcohol use during pregnancy, high milk intake and more spontaneous abortions delivered babies with lower cord BL.

5. Women who use lead-glazed pottery
Risk for lead exposure may be culturally specific. Case reports of acute blood lead elevations related to use of traditional products or practices include samovar use (Gulson), ingestion of lead shot in Innuit women who consume hunted game animals (Levesque) and in Andean women living in villages with widespread use of lead glazing compounds (Counter). Of all the culturally specific practices and products that may put pregnant women at risk for lead exposure, the use of lead glazed pottery is perhaps the best documented in the literature.

Use of lead-glazed pottery to cook was found to be a strong predictor of BLL and tibial and patellar lead by Brown. Tibial lead was found to be highest if women used pottery as child and lower with current, but not past, use. (Tibial is cortical bone with long half life). (Occup Environ Med 2000; 57:535-541)

In the study by Farias in Mexico City, regression models indicated that in women from public hospitals, a main determinant of BLL was use of lead glazed ceramics. (Environ Health Perspective 1996; 104: 1070-1074)

In a cross sectional questionnaire study of 99 random housewives of mid to low socioeconomic status in Mexico City, Hernandez Avila et al. (24--Hernandez Avila, 1991) found blood lead levels of 1-52 mcg/dL. Five percent had BLLs over 25 mcg/dL and 22 percent had BLLs over 15 mcg/dL. The main determinants of BLL were higher SES which was inversely related and the use of lead-glazed ceramics for food preparation—mainly stew which was positively related. The population attributable risk for BLL >15 mcg/dL due to the use of lead-glazed ceramics was 58 percent.

In a cross sectional pilot study of blood (and bone) lead levels among 98 recently postpartum women in Mexico city, Hernandez Avila et al. (23--Hernandez Avila, 1996) found that significant predictors of higher blood lead levels were a history of preparing or storing food in lead-glazed ceramic ware, low milk consumption and higher levels of lead in patella bone. Significant predictors of patella bone lead included years living in Mexico City, lower consumption of high calcium content foods and nonuse of calcium supplements. The study suggests that patella bone is a significant contributor of blood lead during lactation.

In a case study of one Hispanic pregnant woman in California, Hamilton et al. (21--Hamilton, 2001) found blood lead levels of 119.4 in the woman and 113.6 in the cord blood at delivery. The woman practiced a form of pica in which she broke a lead-glazed clay pot from Mexico into small pieces and eat several pieces daily. They found that this practice was apparently not uncommon in Mexican women.

A relationship between maternal and child (family) blood lead levels was noted by Azcona-Cruz et al, who measured blood lead levels in children 8-10 years and their mothers in Oaxaca and found a high correlation between maternal and child BLL. and association between child BLL and family use of lead-glazed pottery and animal fats for cooking. There was also an association of child BLL and family income. (Arch Environ Health 2000; 55:217-222)

In a study of Mexican women in New York city Klizetman et al found that women who used imported spices or pottery or eat soil were are increased risk for elevated blood lead levels.
Leighton et al. *(33--Leighton, 2001)* in the Annual Report 2001 for Preventing Lead Poisoning in New York City, provided data on 40 lead poisoned pregnant women: 95 percent were foreign born (60 percent were from Mexico) and 20 percent reported eating dirt, clay or crushed pottery during their current pregnancy. Other pathways included consumption of imported foods and spices that contain lead and regular use of lead-glazed pottery in food preparation. None of the women were exposed to lead at work.

Romieu et al report in their 1994 review article on the major sources and pathways for lead exposure in Mexico via a review of published studies. They discuss a study from Rothenberg [Rothenberg SJ, Perez Guerrero IA, Perroni-Hernández E, Schnaas-Arrieta L, Casino-Ortiz S, Suro-Cárcamo D, Flores-Ortega J, Karchmer S. Sources of lead in pregnant women in the valley of Mexico. *Salud Publica Mex* 32:632-643(1990)] which showed that among a cohort of pregnant women and their offspring, women who used lead glazed ceramics and their infants had higher blood lead levels than women who did not use this type of pottery. The findings demonstrate the major role of traditional pottery as a contributor to blood lead levels in the general Mexican population and emphasize the need for interventions to produce lead-free pottery.

Rothenberg et al (1996) studied Mexican women of low to middle SES from 12 weeks of pregnancy to delivery to determine factors that explain the relationship between cord BL and maternal BL. They found from 245 paired maternal-cord BL samples that older mothers using lead-glazed pottery and canned foods delivered babies with increased cord BL.

**6. Women who eat non-food items**

Although not specifically considering lead or other possible contaminants of geophagy or clay-eating, Hunter *(27--Hunter, 1973 & 28--Hunter, 1973)* provided a cultural geographic analysis of this practice in Africa. Hunter argued that geophagy is a behavioral response to physiological stress. The African clay contained many of the minerals found in modern supplements and was probably beneficial to the nutrition of pregnant women and others who ate it. This practice came to the U.S. through the slave trade and possibly from later African immigrants. As migration took African Americans to northern cities where appropriate clay was no longer available, starch-eating (amylophagia) was substituted but it had none of the nutritional value except calories.

In an ecological study conducted on linking cattle rearing and geophagia, Wiley et al found increased clay eating in populations that did not hear cattle or where women were not given access to milk. She hypothesized that clay provides important nutrients primarily calcium but may also have a role in reducing absorption of teratogens during early pregnancy.

In another cultural geographic analysis, again without discussion of lead, Hunter and DeKleine *(29--Hunter and DeKleine, 1984)* described geophagy in Central America which was blessed by the Catholic clergy from Spain and came to the U.S. through Hispanic immigration.
In an anthropological analysis also not referring specifically to lead, Kehoe and Giletti (Kehoe and Giletti, 1981) argued that historic, severe, nutrient deficiencies in pregnant and lactating women might have led to behavioral abnormalities that were thought to indicate spirit possession.

Abrahams in a review of geophagy, the habit of eating clay or earth, points out that geophagy appears to result in a syndrome of concurrent iron deficiency and hypokalemia (cachexia africana). It is not clear if this is cause or consequence of geophagy, since soil can provide needed minerals such as iron and calcium or can bind them and lead to deficiency. Soil intake may be large, with pregnant women in Africa consuming an average of 30-50 grams of soil per day (Geogr J 1996; 162:63-72).

Boyle defined pica as a habit of eating nonfood substances and stated that substances linked with pica in US include starch, clay, dirt, ashes, plaster, hair, burnt matches, small stones, and refrigerator frost or ice. Starch eating is more frequent among African American women and clay among Hispanic women. The cause of pica was pointed out as unknown but it is associated with malnutrition. There is also a link between pica and iron deficiency but cause versus consequence is in question. (J Transcultur Nurs 1999;10:65-68)

Pica practice in low-income, English speaking, women attending a rural U.S. Southern clinic was described by Corbett. 38% were found to practice pica, ingesting over one cup of ice a day, but also there was ingestion of freezer frost, starch, clay dirt, baked clay dirt, or multiple items. In those with pica, 77% practiced daily and many had a family history of pica (60%). African-American ethnicity was the only demographic variable associated with pica. Lower hematocrit was found in women practicing pica daily versus intermittent. (MCN Am J Matern Child Nurs 2003; 28:183-189)

Pica in African-American women attending prenatal clinic in Washington DC was studied prospectively by Edwards in 1985-1991. There was consumption of ice or freezer frost by 6.9% of the women, with occasional consumption of starch and baking soda; but no clay or dirt was indicated as consumed. 28% had seen others eat non-foods, such as starch, clay and ice. Hemoglobin and ferritin were significantly lower in pica than non-pica women and iron and calcium intakes were lower (though intakes not significantly lower). (J Nutr 1994; 124 (6 Suppl):954S-962S.)

Rainville conducted a retrospective cohort study of 281 WIC mothers aged 16-30 that had an infant <1 year of age. Questions about pica were administered and their medical records were reviewed. Fifty-four percent of women reported eating ice, 15% reported eating ice and freezer frost, 8% reported eating starch/powder/clay or dirt and 23% reported no pica. Similar to the Edwards article (above), lower hemoglobin levels were found at delivery among women who reported pica behavior vs. those that did not. There were no differences in mean birth weight or mean gestational age of infants born to the women b/w the pica and non-pica groups. BLLs were not considered in the study. (Rainville AJ. Pica practices of pregnant women associated with lower maternal hemoglobin level at delivery. J Am Diet Assoc 1998;98(3)293-296).
Simpson E et al (2000) concluded that the high reported rate of pica among Mexican-born women (44% of 150 women interviewed in Ensenada, Mexico and 31% of 150 women interviewed in S. California) indicates that all Mexican born women in the US should receive a screening for pica and education about the serious health effects to the mother and fetus (W J Med vol 173, 2000).

Smulian JC et al (South Med J 1995) studied pica characteristics among 125 women at their first antenatal visit in rural Georgia. Pica was found in 14.4% of the women. Study data suggested that pica practices are associated with similar practices during childhood and non-pregnant states.

In a study of Mexican women in New York city Kliezteman et al found that women who eat soil were at increased risk for elevated blood lead levels.

Sule S et al (Nigerian J of Med, 2001) interviewed 62 newly delivered mothers in a teaching hospital in Zaria, Africa to determine the prevalence of pica and factors associated with pica. Pica prevalence was found to be 50%. The prevalence of non-food pica was significantly higher than that for food pica (17.8% diff). There was a significant association b/w pica in family, friends or other members of the community and pica in the index pregnancy.

Shannon M (2003) reviewed cases of 7 severely lead poisoned women (BLLs >=45) over a 3 year period and an additional 8 from the med. lit. Most were Hispanic. He found that severe lead poisoning in these women most often occurs because of intentional pica; presenting features are mostly subtle with only malaise and anemia; and that BLLs are higher in neonates than simultaneous maternal BLLs.

In a quasi meta-analysis on the literature on pica among pregnant women from 1950 through 1990, Horner et al. (26--Horner, 1991) found that women at high risk of pica were more likely to be Black, live in rural areas and to have a positive childhood or family history of pica. They further found that the pica among high risk groups declined between the 1950s and the 1970s but remained steady through 1990. They advise dietetic counselors to ask questions about pica during nutritional assessments.

Boyle presented a case history that illustrated that several interviews may be needed until health care giver learns of pica habit and need to ask directly about it (J Transcultur Nurs 1999;10:65-68) Corbett found that few medical records had history of pica noted. (MCN Am J Matern Child Nurs 2003; 28:183-189)

7. Women who use complementary and/or alternative medicines and therapies

Most of the articles reviewed here did not tie use of these therapies to elevated BLLs, but use of herbal and traditional remedies have been tied to lead poisoning in children (see below) and in adults (MMWR article on East Indian medicines, July 9, 2004). Further, many of the alternative therapies used are self administered, without visit to a related practitioner.
In a case study of one 45-year old Korean man who drank Chinese herbal tea for medicinal purposes Markowitz et al. (35--Markowtz, 1994) found a blood lead level of 76 mcg/dL. The lead exposure was found to be hai ge fen (clamshell powder), one of 36 ingredients in the tea which had become adulterated with lead.

Cheng described that 6 of 8 children found to be taking herbal medicines had elevated BLLs > 10 micrograms per dL. Univariate associations were found between BLL and taking herbal medicine, drinking tap water, and having a relative who was lead poisoned. In further multiple regression analysis only the taking of the herbal medicine Ba-baw-san was associated with BLL. There were strong associations in BLLs across sib-ships. (Occup Environ Med 1998; 55:573-576)

Use of Greta was described in a lead poisoned two year old in a report in MMWR and review of 1991-1992 California data yielded 40 cases with BLLs ≥ 20 micrograms per dL where children had received ethnic remedies. Over 80% of these children had Hispanic names. (MMWR 1993;43:521-524).

In a questionnaire survey of herbal medicine use among 734 women who had recently or were about to give birth in Massachusetts, Hepner et al. (22--Hepner, 2002) found that 7.1 percent reported the use of herbal remedies mostly on the advice of their health care provider. No information about lead contamination of herbal remedies was provided.

Eisenberg et al, through a random digit dialing, national telephone survey to adults ≥ 18 years of age and English speaking, gathered information on alternative medicine practices in 1990. Overall about 10% of respondents went to a provider of unconventional therapy but 34% reported using at least one unconventional therapy in the past year, even if they didn’t see provider of these therapies. Highest use was in age 25-49, non-black individuals. Majority paid out of pocket for unconventional therapy. And 72% did not tell their medical doctor that they used unconventional therapy. (N Eng J Med 1993; 328: 246-252)

In a follow-up national telephone survey, Eisenberg et al looked at alternative medicine practices again for 1997. They found that use of alternative therapies increased to 42% (from prior 34%) and use was more common in women than men. Therapies increasing in usage included herbal medicine, megavitamins, and folk remedies, among other therapies. More than 60% did not tell their medical doctors that they used alternative therapies and the majority still paid out of pocket for these therapies. (JAMA 1998; 280: 1569-1575)

Use of alternative therapies, specifically by women age 18- 80 years old, was studied by Factor-Litvak et al, in New York City. The random digit dialing survey was stratified to equally include Anglo/White, African- American, Hispanic/ Latino women, with each group divided equally into 18-40 and 41-80 year old subgroups. They looked at 3 categories of complementary and alternative medicine (CAM): medicinal/ herbal; techniques (mind-body); and manual (e.g. massage, acupressure). They found that 58%of women used some form of CAM and 41% saw a CAM practitioner. 47% used medicinal therapies, 25% manual therapies, and 20% mind-body. There were no differences in frequency and type of CAM use across race/ ethnicity or age.
groups. The type of practitioners reported as used most were chiropractors, nutritionists, and massage therapists. (J Altern Complement Med 2001; 7: 659-666)

Tait PA et al (MJA 2002; 17:193-195) report on a 24 year-old woman from India who immigrated to Australia and who delivered a child there with a neonatal BLL that was the highest recorded for a surviving infant in the country (cord BLL was 7.6 umol/L). An exposure assessment revealed the mother’s long-term ingestion of lead-contaminated herbal tablets as the source. The child was successfully chelated.

Wiley AS and Katz SH (Curr Anthropol 1998) investigated the relationship between geophagy (the practice of eating dirt), diet and dairying practices among African populations by reviewing 48 Human Relations Area Files (collections of ethnographies and archaeological articles) to search for references to geophagy. Fifteen reports (i.e., population studies) were found to reference geophagy in this dense but interesting report. Clay was found to be most often consumed by women in small amounts throughout the day. It appeared to be more of a snack food than a food consumed at a meal. A significant difference in the frequency of geophagy by pregnant women was found b/w dairying and non-dairying populations (p<0.001). Populations for which pregnancy geophagy is reported are clustered in the western and central areas of sub-Saharan Africa. The authors note that extensive clay trade networks exist throughout these regions and local ecological conditions contribute to the formation of rich sources of clay. The results of the survey show that geophagy during pregnancy is inversely related to the practice of dairying (i.e., dietary sources of calcium in diet). The authors also discuss evidence of low calcium intake in the diets of agricultural populations in tropical Africa. The authors also discuss the amount of calcium that clays can provide to pregnant women and conclude that clay seems to be an important component of the biocultural management of pregnancy. The authors also conclude that geophagy during the first trimester of pregnancy may reduce both the discomfort of and the loss of nutrients through pregnancy sickness while providing additional protection against potentially toxic secondary compounds that are likely to be ingested by women eating heavily plant-based diets.

8. Women who come into contact with lead industry workers (take home exposures).

In a cross sectional program of screening of blood lead levels and education among 93 workers (96 percent male) and seven worker-children pairs from 24 radiator repair shops in New York City in 1986-7, Nunez et al. (38--Nunez, 1993) found that for the 93 workers: 41 with BLLs <25 mcg/dL, 28 with BLLs 25-39 mcg/dL, 13 with BLLs 40-49 mcg/dL and 11 with BLLs >= 50 mcg/dL. BLLs for the seven worker-children pairs ranged from 4-21 for the children and 21 to 36 for the workers. This study demonstrates the likelihood that male radiator repair workers may take lead home and expose their children. It did not specifically demonstrate lead exposures to wives of these workers.

In a prospective cohort study of pregnant women in Yugoslavia, Graziano et al. (20--Graziano, 1990) primarily looked at lead exposures in relation to distance of residence from a lead smelter. However, relating to take-home lead, they found the husband’s employment in the lead industry
was associated with a significant increase in maternal blood lead levels independent of the distance of residence from the smelter.

In a retrospective cohort study of birth certificates in 1981-82 in New York, Lin et al. (34–Lin, 1998) looked at the relationship between paternal occupational lead exposure and low birth weight or prematurity. No statistically significant differences in birth weight or gestational age between the exposed (workers in the NY Heavy Metals Registry) and controls (bus drivers) were found. No estimates of lead exposures for the wives during pregnancy were given.

Baghurst et al, in 1979-1982, found BLL was also increased for women whose husbands were smelter workers.

Roche, LM reported on the first full 11 years of the NJ adult lead registry. The article did not offer any information about women who come in contact with lead industry workers (i.e., describe take home exposures or discuss women or pregnant women) (Roche LM, et. al. 1998).

Roscoe et al (1999) conducted a meta-analysis of all available reports of take-home lead exposures. The study objective was to estimate the blood lead levels among U.S. children (ages 1-5) from households with lead exposed workers. Based on a meta-analysis of 10 reports from 1987 through 1994, the children (n=139) of lead-exposed workers (n=222) had a geometric mean blood lead level of 9.3 mg/dL compared to a U.S. population geometric mean of 3.6 mg/dL (p=0.0006). Also in this group, 52% of the children had blood lead levels (BLLs) >= 10 mg/dL compared to 8.9% in the U.S. (p=0.0010), and 21% of the children had BLLs >= 20 mg/dL compared to 1.1% in the U.S. (p=0.0258). The authors estimate, based on 1981-83 survey data, that there are about 48,000 families with children under six living with household members occupationally exposed to lead. The study did not discuss adult population BLLs.


In a convenience sample of 108 minority subjects recruited in 1999-2000, Lin et al found bone and blood lead levels that were similar to community-exposed white subjects of similar age.

Applying logistic regression analyses to NHANES II data, Geronimus and Hillemeier (Ethnicity Dis, 1992;2:222-231) showed that sizeable percentage of women of childbearing age in general and childbearing black women in particular may have blood lead levels that may place them at risk for poor reproductive outcome.

Klitzman and colleague, using New York State blood lead data, (J Urban Health, 79(2), 2002:225-237) concluded that lead poisoning among pregnant women in urban multiethnic settings is a significant problem.

10. Women with evidence of previous lead exposure (usually bone lead levels higher than the general population)
Gulson found that as dietary lead decreases, the bone becomes an important contributor of lead to blood. This finding is consistent with findings of higher blood lead levels in post-menopausal versus pre-menopausal women (Nash, others).

Raymond et al described a case of a 31 y.o. pregnant woman whose BL was 31 during pregnancy and 75-85 postpartum. The woman had lumbar lead bullet fragments (from a gun shot wound several years previous) which were hypothesized to cause the large increase in BLL because they became disturbed from the weight of the gravid uterus after being dormant for the previous 15 years. The infant’s BL was also very high. The case demonstrates a remarkable gestational rise in maternal BLL. (Raymond LW, et al 2002)

In a pilot study using a cross-sectional, convenience sample of 24 rural Mexican women, Moline et al. (36--Moline, 2000) found a significant inverse relationship between months of lactation and age-adjusted calcaneus lead level. No significant relationship was noted with age-adjusted patella or tibia lead level. Bone and blood lead levels were observed to be 77 percent higher in these rural Mexican women than in urban New York City women. Blood lead levels were positively associated with the use of lead-glazed ceramics. This study provides limited evidence that lead mobilization occurs during lactation.

In a cross sectional pilot study of blood (and bone) lead levels among 98 recently postpartum women in Mexico city, Hernandez Avila et al. (23--Hernandez Avila, 1996) found that significant predictors of higher blood lead levels included higher levels of lead in patella bone (but not tibia). A 34 mcg/g increase in patella lead was associated with an in 2.4 mcg/dL increase in blood lead. Significant predictors of patella bone lead included years living in Mexico City, lower consumption of high calcium content foods and nonuse of calcium supplements. The study suggests that patella bone is a significant contributor of blood lead during lactation. Consumption of high calcium content foods may protect against the accumulation of lead in bone.

Kosnett 1994 In 101 suburban residents K-XRF tibial bone Pb and BPb were measured. Predictors for bone Pb were age, sex, pack-years of smoking, and inversely, having ever nursed. No prevalence data.

Moline 2000 24 maternal aged women studied by K-XRF at calcaneus patellar and tibia sites. Calcaneus Pb, but not patellar (also a trabecular bone) and not cortical bone, decreased with increasing lactation durations and increased with age. Greater body mass and smoking were associated with increased cortical bone Pb. BPb associated with lead-glazed ceramic use. No prevalence data.

Rothenberg 2000 311 immigrant Latino women with KXRF during 3rd trimester and 1-2 months post delivery (1696 women did not return for 2nd visit). BPbs were low (2.2). Postnatal BPb was sl. higher than 3rd trimester (2.2 vs 2.8). Bone Pbs means were imprecisely characterized but showed slightly elevated means suggesting past Pb exposure, though lower than expected for former Mexican citizens. In models developed, calcaneus Pb was associated with yrs in U.S.; tibial Pb with hrs in bed and use of folk remedies. 3rd trimester BPb was associated with calcaneus and tibial Pb, daily calcium, yrs in U.S. and hrs in bed. Postnatal BPb was associated
with 3rd trimester BPb, calcaneus Pb, and lead-glazed pottery. No prevalence data - special population.