Bull Environ Contam Toxicol (2012) 88:145–149
DOI 10.1007/s00128-011-0475-9

Lead Levels in Breast Milk, Blood Plasma and Intelligence Quotient: A Health Hazard for Women and Infants

C. Prince Jebadass Isaac · A. Sivakumar · C. Rebecca Prem Kumar

Received: 25 August 2011 / Accepted: 12 November 2011 / Published online: 22 November 2011

Abstract Lead levels in human breast milk and blood plasma or serum were analyzed and qualitatively their intelligence quotient (I.Q.) studied. Samples at different stages of lactation, from 5 days to 51 weeks post partum, were collected from 25 healthy breast-feeding mothers in Ranipet Industrial area of Vellore district of Tamil Nadu and from 25 lactating mothers in the non-industrial areas of the same district. The samples from mothers in non-industrial area showed lower lead levels ranging from 5 to 25 μg/L whereas samples from mothers in industrial area showed higher lead levels ranging between 15 and 44.5 μg/L. It was generally noticed that the lactating mothers from industrial area have lower I.Q. levels compared to mothers from non-industrial area.

Keywords Lead (Pb) · Breast milk · Intelligence quotient (I.Q.) · Human

Several aspects of human feeding have similar biological relevance as feeding breast milk during the early stages of pregnancy and during the initial postnatal months (Koletzko et al. 1998) and it is widely accepted that human milk provides all the required nutrients, including essential trace elements required by the normal term newborn infant (Bates and Prentice 1994). Conversely, human milk can also be a transfer medium for undesirable (toxic) elements from the mother to the infant. The nutritional factors of the lactating woman influence structural, hormonal and behavioral aspects of the infants (Chierici et al. 1998). Lead (Pb), cadmium (Cd) and mercury (Hg) are potentially toxic heavy metals with hematotoxic, neurotoxic, and nephrotoxic effects even at very low concentrations (Yang et al. 1997). Infants are understandably more vulnerable to heavy metal exposure because of their rapid growth, the physiologic immaturity of their organs and the susceptibility of the sensitive central nervous system during the first year of their lives. Infants and young children may absorb as much as 50% of dietary Pb compared to only 10% by adults.

During lactation, Pb is thought to be transported from maternal plasma to mammary gland (Namihira et al. 1993) and secreted into breast milk along with copper (Cu) and zinc (Zn). However, the interaction between Pb and Cu or Zn has not been understood clearly, particularly in breast milk. There is a good level of understanding the role of major nutritional elements like calcium (Ca), magnesium (Mg), phosphorus (P), sodium (Na) and potassium (K) in breast milk during the growth and development of the infants but the effects of Pb on their metabolism have not been sufficiently investigated (Ziegler et al. 1978). Especially Ca in breast milk is reported to come from maternal bone because of a decrease in maternal bone density noticed during the lactation period. However, the effect of Pb exposure on Ca or other elements related to Ca secretion in human breast milk is also not clear. The purpose of this study was to quantify Pb levels in human breast milk, plasma serum and understand if these levels have any effect on the intelligence quotient (I.Q.) of women living around industrial area (Set A) in comparison with women living in non-industrial areas (Set B) of Vellore district.

C. P. J. Isaac · A. Sivakumar (✉)
Environmental and Analytical Chemistry Division, VIT University, Vellore, Tamil Nadu, India
e-mail: svkmr7627@gmail.com

C. R. P. Kumar
Department of Histopathology, Christian Medical College and Hospital, Vellore, Tamil Nadu, India

Materials and Methods

The subjects were 50 women aged 20–45 years, comprising 68% of the women who delivered their infants at Hospitals, within Vellore who had sufficient breast milk to provide samples after feeding their babies. The subjects were all Tamilians from South India and from industrial and non-industrial areas of Vellore district. More than 70% of them were housewives whose most common job before marriage was office work where heavy metal accumulation in their body is a rarity. Several subjects donated samples at various stages of their lactation. Each subject obtained code identification (PbIA 01-25 for Industrial mothers, and PbNIA 26-50 for non-industrial mothers) and had to fill out a personnel questionnaire (Tables 1, 2). Altogether, breast milk samples from 5 days to 51 weeks post partum were collected in this study (Gulson et al. 1998). Therefore, the samples comprised both transitory and mature milk. There were no significant differences in nutritional status or health management practices between the subjects who participated in the present study and those who did not (Richard et al. 2003). Informed consent for this study was obtained from all subjects in the appropriate manner. Information about occupational exposure to Pb, residence in a Pb contaminated area and passive smoking was obtained via a questionnaire filled out by the subjects themselves.

Woodcock-Johnson Tests of Cognitive Abilities-III was performed to check whether the I.Q. levels of mothers from both industrial and non-industrial areas are low (Richard et al. 2003). Mothers were assessed, with tests vocabulary, spatial pattern analysis, quantitative ability, and memory. Composite score mean (±SD), was used to represent I.Q., because it is similar to the I.Q. score of other intelligence tests. A different examiner administered an abbreviated Woodcock-Johnson Tests at each age. Examiners were unaware of mother's lead levels. An I.Q. under 70 is considered as "mental retardation" or limited mental ability. However, it should be understood that even low blood Pb levels (BPb) levels can also be harmful as it is

Table 1 Data of participating breast-feeding mothers from industrial area, Vellore district (South India)

Subject codes	Age (years)	Height (cm)	Weight (kg)	Lactation periods (weeks)	Additional children (n)
PbIA01	35	166	60	8	1
PbIA02	39	171	55	7	0
PbIA03	41	165	71	16	1
PbIA04	32	156	65	15	0
PbIA05	38	163	60	.7	0
PbIA06	30	165	75	.5	2
PbIA07	28	143	65	4	2
PbIA08	33	163	57	12	0
PbIA09	31	165	75	.5	2
PbIA10	33	165	72	3	2
PbIA11	35	171	55	7	0
PbIA12	35	165	75	.5	2
PbIA13	36	163	66	.7	0
PbIa14	33	160	60	.5	0
PbIA15	30	164	51	2	0
PbIA16	32	143	61	10	0
PbIA17	33	155	50	11	0
PbIA18	30	160	57	2	0
PbIA19	31	163	67	.4	0
PbIA20	29	143	51	12	1
PbIA21	27	144	50	2	0
PbIA22	25	165	57	12	0
PbIA23	29	133	51	4	0
PbIA24	29	166	53	12	0
PbIA25	30	143	51	12	0

Table 2 Data of participating breast-feeding mothers from non industrial area, Vellore district

Subject codes	Age (years)	Height (cm)	Weight (kg)	Lactation periods (weeks)	Additional children (n)
PbNIA26	30	165	73	4	0
PbNIA27	44	153	47	5	1
PbNIA28	32	160	65.5	.7	2
PbNIA29	32	157	67	4	0
PbNIA30	40	180	68	2	1
PbNIA31	29	173	59	4	0
PbNIA32	36	168	57	3	1
PbNIA33	41	162	59	2.5	1
PbNIA34	35	160	47	4	2
PbNIA35	32	176	65	3	1
PbNIA36	37	175	69	3	0
PbNIA37	26	158	64	2	1
PbNIA38	33	164	61	1	0
PbNIA39	41	153	66	.5	0
PbNIA40	34	167	68	3	1
PbNIA41	34	163	71	2	0
PbNIA42	36	158	53	1	1
PbNIA43	38	169	67	2	0
PbNIA44	35	159	56	2	1
PbNIA45	33	170	75	3	0
PbNIA46	32	158	62	1.5	0
PbNIA47	32	169	70	3	1
PbNIA48	29	161	50	1	0
PbNIA49	31	160	58	3	0
PbNIA50	32	170	61	4	0

well reported that BPb levels of 10 µg/dl lowers the I.Q. by 3–5 points.

Plasma/serum and transitory milk samples were collected into polypropylene tubes on the 5th post partum day or 8th day in subjects with delayed milk excretion because of cesarean section (CS). The samples were kept frozen at −20°C until analyses. The working solutions were prepared daily by accurate dilution with Millipore water. All blood samples were collected after a 12 h overnight fast. Whole blood was collected in ethylene diamine tetraacetic acid (EDTA) tubes (Vacutainer® Becton Dickinson) and contamination in the collection and handling of samples was avoided (Grandjean et al. 1995; Pronczuk et al. 2002). Atomic absorption spectrophotometer (Perkin Elmer, A Analyst 200) was used for estimation of Pb levels (Casey et al. 1989; Hannan et al. 2005).

The average levels of the metal for each mother from Set A was obtained from two or more specimens prepared/digested from the same sample and triplicate measurements of each digest; then, the mean of the mean was formed and expressed as arithmetic mean (SD). The Pb levels in breast milk samples were observed to be between 5 and 65 µg/L in samples from Set A while these levels were found to be 21.5 and 13.21 µg/dL in the milk of samples from Set B. (Figs. 1, 2) shows Pb levels observed in different breast milk samples donated from Set A and Set B subjects. It could be seen that the Pb levels were higher in Set A samples and showed significant difference from Set B samples of Vellore district.

It is assumed that the passage of these trace elements from blood to milk does not occur by passive diffusion but by regulated transport through the mammary gland epithelium (Domell et al. 2004). The levels of trace elements and toxic elements in breast milk can vary considerably during the course of lactation. For instance, the levels of the essential elements molybdenum (Mo) or zinc (Zn) were found to be reducing with duration of lactation (Rossipal and Krachler 1998). In addition, the concentrations of the toxic elements, mercury (Hg) and lanthanum (La) were higher in colostrums than in mature milk (Wappelhorst et al. 2002).

Results and Discussion

However, in the present study a significant decline in the Pb levels was noticed in the breast milk of the Set B mothers in comparison with samples from Set A mothers. Pb concentrations in breast milk and blood plasma samples of the lactating mothers from Set A and Set B are shown in Table 3.

All Pb concentrations in the human plasma samples from Set B mothers, except two, were in the order of 10 µg/L. However, the serum samples of Set A mothers

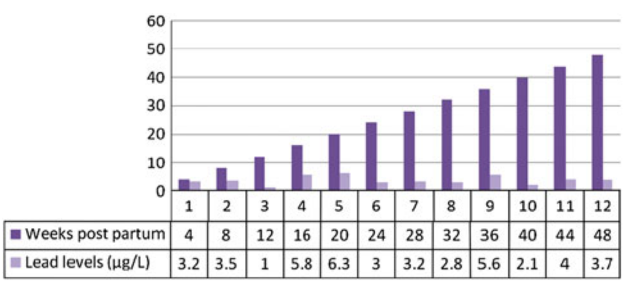

Fig. 1 Mean lead (Pb) concentrations in human breast milk of lactating mothers from Set B as a function of time after delivery (weeks post partum)

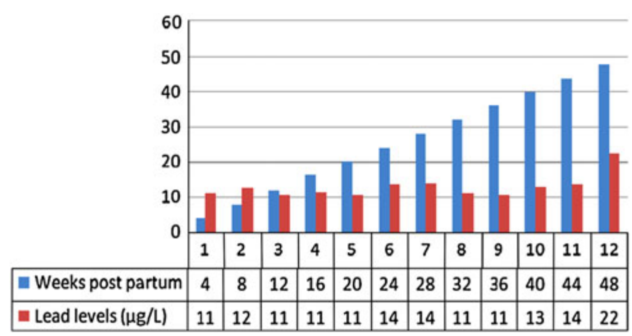

Fig. 2 Mean lead (Pb) concentrations in human breast milk of lactating mothers from Set A as a function of time after delivery (weeks post partum)

Table 3 Concentration of lead in breast milk and blood plasma/serum of lactating mothers living around industrial (Set A) and non-industrial areas (Set B)

Milk	No. of samples (n)	Range (µg/L)	Mean (µg/L)	Median (µg/L)	n < LOQ[a]
Set 'B'	25	9–21	13.21 (5.2)	13	4
Set 'A'	25	15–25.5	21.5 (4.5)	18	3
Plasma/serum	**No. of samples (n)**	**Range (µg/L)**	**Mean (µg/L)**	**Median (µg/L)**	**n < LOQ[b]**
Set 'B'	25	10–13.5	10 (4.8)	11	3
Set 'A'	25	18.5–44.5	35.4 (11.4)	38	0

[a] Non-industrial area (Set B)

[b] Industrial area (Set A)

from showed Pb values ranging from 18.5 to 44.5 μg/L. These higher Pb levels in the serum of Set A mothers, compared to Set B mothers could be because of a higher daily Pb intake by ingestion or inhalation. Pb is immediately taken up at high rates from inhalative exposure and is transported via blood to other organs, as demonstrated in an animal experiment from Shiao-Shan et al. (1988). A possible source of Pb in the ambient air could be the widespread use of catalysts in automobiles and the usage of Pb in various industries like paints, pigments, steels and dyes etc. (Gundacker et al. 2002; Sharma and Pervez 2005). Thus, a higher intake of Pb by inhalation of Pb in particulate matter could be argued due to the water contamination of industrial areas.

The most interesting aspect in the present study is the interaction between Pb and major nutritional and trace elements (Eckhardt et al. 2001; Myers and Davidson 2000) in breast milk, because the nutritional function of milk is important for infant health. In the liver or kidney, the interactions of Zn and Pb or Cu and Pb are well known from the earlier literature, but their relation in breast milk is not clearly reported. The differences in the secretion mechanisms, in which metallothionein is not involved, between Pb and Cu or Zn in breast milk, need to be investigated further (Taylor et al. 2005; Rydzewska and Krol 1996). The mean lead (Pb) concentrations in human breast milk of lactating mothers from Set A and Set B are categorized with regard to age (Fig. 3).

The Woodcock-Johnson Tests of Cognitive Abilities-III carried out to know the I.Q. levels of Set A and Set B mothers. The results from the I.Q. test were interesting as the I.Q. levels of Set A mothers was observed to be lower as compared to Set B mothers, which might have relevance to higher Pb exposure of Set A mothers. The I.Q. levels compared with lead levels are shown in Fig. 4.

The present study brings out a reasonable understanding on increased Pb levels in breast milk, plasma and interestingly, makes an observation of low I.Q. levels of women living around the industrial areas of Vellore district in comparison with mothers living in non-industrial areas the details of which will be a target of future work.

The results in the present study show that the higher levels of Pb in mother's milk can be because of enhanced intake of Pb by mothers in industrial areas of Vellore district, compared to mothers in non-industrial areas, through particulate matter emissions due to large number of steel, paint and chemical industries. Depending on the levels of Pb in the environment, varying Pb values in plasma/serum could be present. An increased level of Pb in human breast milk and plasma/serum could be explained because of continuous exposure to the polluted environment. Hence, the infants are expected to have higher intake of Pb through mother's milk and therefore, are exposed to potential health related issues based on Pb levels and associated toxicity, which is of a serious concern to the society and needs to be addressed.

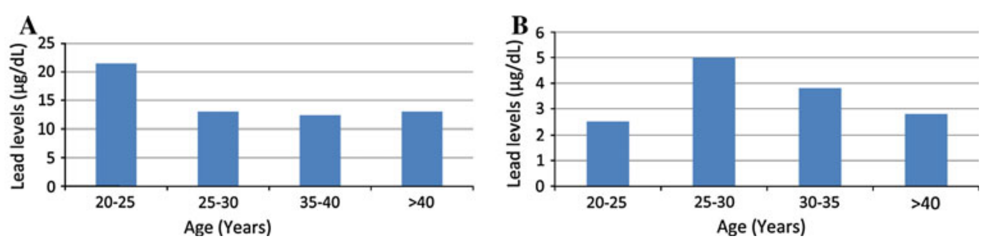

Fig. 3 Mean lead (Pb) concentrations in human breast milk of lactating mothers from Set A and Set B are categorized with regard to age

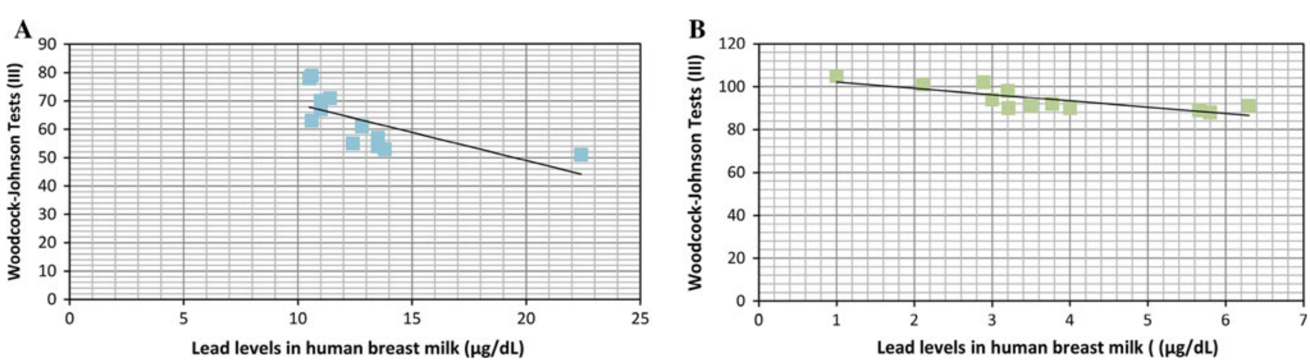

Fig. 4 I.Q. test results compared with lead levels in breast milk for Set A and Set B samples

Acknowledgments The authors thank VIT University, Vellore and Tychicus. D, Selvin James. S for their help in sample collection and determination of actual concentrations of toxicants.

References

Bates CJ, Prentice A (1994) Breast milk as a source of vitamins, essential minerals and trace elements. Pharmacol Ther 62: 193–220

Canfield RL, Henderson CR Jr, Cory-Slechta DA, Cox C, Jusko TA, Lanphear BP (2003) Intellectual impairment in children with blood lead concentrations below 10 microg per deciliter. N Engl J Med 348:1517–1526

Casey CE, Neville MC, Hambidge KM (1989) Studies in human lactation: secretion of zinc, copper, and manganese in human milk. Am J Clin Nutr 49:577–585

Chierici R, Saccomandi D, Vigi V (1998) Dietary supplements for the lactating mother. Influence on the trace element content of milk. Acta Paediatr Suppl 88:7–13

Domell M, Lonnerdal B, Dewey KG, Cohen RJ, Hernell O (2004) Iron, zinc, and copper concentrations in breast milk are independent of maternal mineral status. Am J Clin Nutr 79: 111–115

Eckhardt CL, Rivera J, Adair LS, Martorell R (2001) Full breast-feeding for at least four months has differential effects on growth before and after six months of age among children in a Mexican community. J Nutr 13:2304–2309

Grandjean P, Weihe P, Needham LL, Burse VW, Patterson DG Jr, Sampson EJ, Jorgensen PJ, Vahter M (1995) Relation of a seafood diet to mercury, selenium, arsenic, and polychlorinated biphenyl and other organochlorine concentrations in human milk. Environ Res 71:29–38

Gulson BL, Jameson CW, Mahaffey KR, Mizon KJ, Patison N, Law AJ, Korsch MJ, Salter MA (1998) Relationships of lead in breast milk to lead in blood, urine, and diet of the infant and mother. Environ Health Perspect 106:667–674

Gundacker C, Pietschnig B, Wittmann KJ, Lischka A, Salzer H, Hohenauer L, Schuster E (2002) Lead and mercury in breast milk. Pediatrics 110:873–878

Hannan MA, Dogadkin NN, Ashuir IA, Markus WM (2005) Copper, selenium, and zinc concentrations in human milk during the first three weeks of lactation. Biol Trace Elem Res 107:11–20

Koletzko B, Aggett PJ, Bindels JG, Bung P, Ferre P, Lentze MJ, Roberfroid M, Strobel S (1998) Growth, development and differentiation: a functional food science approach. Br J Nutr 80:5–45

Myers GJ, Davidson PW (2000) Does methylmercury have a role in causing developmental disabilities in children? Environ Health Perspect 108:413–420

Namihira D, Saldivar L, Pustilnik N, Carreon GJ, Salinas ME (1993) Lead in human blood and milk from nursing women living near a smelter in Mexico City. J Toxicol Environ Health 38:225–232

Pronczuk J, Akre J, Moy G, Vallenas C (2002) Global perspectives in breast milk contamination: infectious and toxic hazards. Environ Health Perspect 110:349–351

Rossipal E, Krachler M (1998) Pattern of trace element in human milk during the course of lactation. Nutr Res 18:11–24

Rydzewska A, Krol I (1996) Contents of zinc, copper and cadmium in mild of women living in Poznan, Ginekol. Polska 67:125–128

Sharma R, Pervez S (2005) Toxic metals status in human blood and breast milk samples in an integrated steel plant environment in central India. Environ Geochem Health 27:39–45

Shiao-Shan Y, Yi S, Hui-Min L, Fu-Shing L, Hui-Juan S, Shui Lang G (1988) Deposition and clearance of 141Ce in the respiratory tract following inhalation of $141CeO_2$ in rats. Ann Occup Hyg 32:957–962

Taylor H, Appleton JD, Lister R, Smith B, Chitamweba D, Mkumbo O, Machiwa JF, Tesha AL, Beinhoff C (2005) Environmental assessment of mercury contamination from the Rwamagasa artisanal gold mining centre, Geita District, Tanzania. Sci Total Environ 343:111–133

Wappelhorst O, Kuehn I, Heidenreich H, Markert B (2002) Transfer of selected elements from food into human milk. Nutrition 18:316–322

Yang J, Jiang Z, Qureshi IA, Wang Y, Wu XD (1997) Maternal–fetal transfer of metallic mercury via the placenta and milk. Ann Clin Lab Sci 27(2):135–141

Ziegler EE, Edwards BB, Jensen RL, Mahaffey KR, Fomon SJ (1978) Absorption and retention of lead by infants. Pediatr Res 12: 29–34