HEALTH RISK ASSESSMENT OF VILLAGERS WHO LIVE NEAR A LEAD MINING AREA: A CASE STUDY OF KLITY VILLAGE, KANCHANABURI PROVINCE, THAILAND

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Abstract. This was a cross-sectional study aimed at assessing environmental lead exposure and its association with blood lead levels, teeth lead levels and IQ of the inhibitants who live near lead mining in Kanchanaburi Province, Thailand. Two hundred fifteen villagers from 6 villages participated in this study. Exposed and non-exposed villagers were asked to perform IQ tests based on Raven's Standard Progressive Matrices. Environmental, blood and tooth samples were collected and analyzed to determine an association with the IQ level. The results showed that soil, vegetables (mint, bitter gourd, Chinese watercress, basil and turmeric) and meat (fish and shellfish) had lead concentrations above the recommended standard. Each person in the exposed group had blood and tooth lead levels higher than 10 µg/dl and 10 µg/g, respectively. The mean IQ of the exposed group was 82.70 ($p<0.05$). The blood and tooth levels in the non-exposed group were lower than 10 µg/dl and 10 µg/g, respectively. The mean IQ scores in the non-exposed group was 96.14 ($p<0.05$). The health risk in the low IQ score exposed group was 5.6 times more than the non-exposed group ($p<0.05$). The IQ scores of the exposed group were significantly inversly associated with the blood lead and tooth lead levels ($r = 0.397$ and 0.129, respectively, $p<0.05$). The children in this study who were exposed to environmental lead had an accumulation of lead in their bodies. This resulted in a great impact on intellectual development. The results reveal that blood lead levels are the best predictor of lead exposure, and the tooth lead levels may provide epidemiological evidence for chronic toxicity. Populations with blood lead or tooth lead levels higher than normal limit should be treated with chelation therapy and health education.

INTRODUCTION

Most people are exposed to environmental lead while breathing air, drinking water, eating foods, swallowing or touching dust or dirt that contains lead. Both children and adults are susceptible to the effects of lead exposure, though exposure pathways and effects differ somewhat. Children spend more time on the ground, where they may contact lead contaminated soil or dust and have hand-to-mouth behavior. Adult exposure is usually occupational and occurs in lead-related industries, such as lead smelting, refining and manufacturing industries. Industrial and mining activities may

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release lead and lead compounds into the air and soil. People living near hazardous waste sites, lead smelters/refineries or other industrial lead sources may be exposed to lead and chemicals that contain lead. Lead may contaminate water, food and alcohol (ATSDR, 1999). Lead may contaminate food during production, processing and packaging. Production sources may include root vegetable uptake from soil lead or atmospheric lead deposition in leafy vegetables. Another source of food contamination is ceramic tableware (Mushak *et al,* 1989; ATSDR, 1999). Lead is distributed in the body in the blood, soft tissue (brain, heart, lungs, liver, spleen, kidneys and muscles) and mineralizing tissues (bones and teeth). The bones and teeth of adults contain more than 95% of the total lead in the body (ATSDR, 1999). The nervous system is the most sensitive target of lead exposure. There is an association between the intelligence quotient (IQ) and lead (Yule *et al,* 1981; Schroeder *et al,* 1985; Landsdown *et al,* 1986; Hawk *et al,* 1986; Fulton *et al,* 1987; Winneke *et al,* 1990).

The village of Klity, 68 miles west of Bangkok, is a Karen indigenous community which has long suffered from poisoning related to lead sediments and contamination in the creek near the village. A lead mine operates and discharges waste directly into this creek, from which the villagers collect their drinking water. Each of the village's 221 inhibitants suffers from lead poisoning (Black Smith Institute, 2004).

The objectives of this study were to assess health risk from environmental lead exposure affecting neuropsychological performance (IQ) and determine an association between blood lead levels and IQ scores of villagers living near the lead mine.

MATERIALS AND METHODS

Population and samples (Fig 1)

This was a cross-sectional study. The study group consisted of 135 people in Klity Lang village, Na Saun sub-district, Si Sawat district, Klity Bon village, Ti Pu Yeh village, Kreung Krawiea village and Hauy Sean village in Chalae sub-district, Thong Pha Phum district, Kanchanaburi Province, Thailand. The population consisted of 89 children and 46

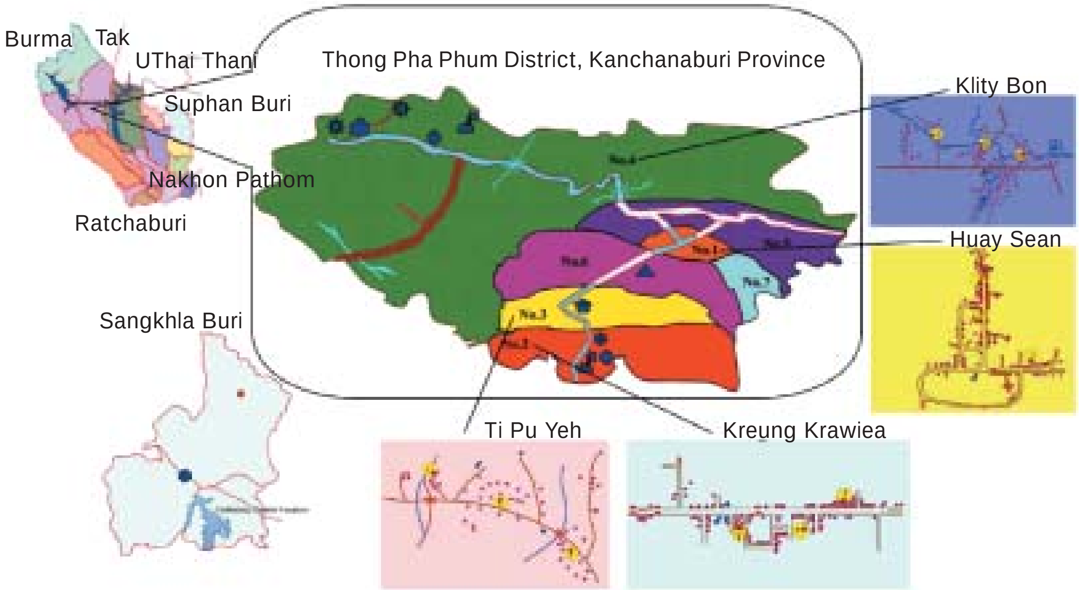

Fig 1–Map of data collection locations.

adults. The control group was 80 people living in Ta Din Daeng village, Yung Kao subdistrict, Sungkhla Buri district, Kanchanaburi Province. This control population consisted of 37 children and 43 adults.

The environmental samples consisted of air, water, soil and food. A variety of foods were tested, including vegetables (mint, basil, Chinese watercress, turmeric, pumpkin, bitter gourd, canton, lemon grass, chilli, rice, thai peper, coriander, and egg plant) and meat (chicken, pork, and fish) in exposed villages and non-exposed villages; 45 samples were taken.

The biological samples consisted of blood tests of the exposed group and the non-exposed group. This resulted in 135 and 48 samples, respectively.

The number of tooth samples in the exposed and non-exposed groups were 135 and 80 samples, respectively.

The neuropsychological tests were performed on 135 and 80 people in the exposed and non-exposed groups, respectively. The test procedure followed the method of Standard Progressive Matrices (SPM) and Color Progressive Matrices (CPM).

The demographic data, health behavior and adverse health effects were collected by questionniare given by a specialist to 135 and 80 people in exposed and non-exposed groups, respectively. The accuracy of questionniare was tested by Cronbach's alpha coefficient method with a resulting coefficiency of 0.64-0.84 which was acceptable criteria.

Research instruments

There were five key instruments used in this study: 1) questionniares to collect demographic data, health behavior, and adverse health effects; 2) the Color Progressive Matrices and Standard Progressive Matrices to assess the intelligence quotient (IQ) of the children and adults; 3) an atomic absorption spectrophometer (AAS) to evaluate tooth lead, blood lead, environmental lead (soil, water) and food lead (vegetables, meat) levels; 4) the air sampling instrument to collect ambient air; and 5) a computer used for statistical analysis of the data.

Data collection

Initial approval was obtained from the Human Research Committee of Burapha University. The research team was comprised of data collecting and data recording assistants who met with community leaders to request cooperation according to procedure and protocol. Each participant gave written informed consent after having the research explained. The data were collected by interviewing 135 people in the exposed group and 80 people in the non-exposed group.

The environmental samples were analyzed by the laboratory of the Pollution Control Department, Ministry of Natural Resources and Environment. The environmental samples were collected by trained technicians from the Department of Environmental Health, Ministry of Public Health. The researcher participated in sample collection. The samples were collected three times at each location.

The blood samples were analyzed by the laboratory of the Occupational Health Department and Kanchanaburi Provincial Public Health Officer from the Ministry of Public Health. The blood samples were collected by trained technicians from the Occupational Health Department. The researcher participated in sample collection.

The tooth samples were collected from the exposed and non-exposed groups by dentists of the Kanchanaburi Provincial Public Health Office. The researcher collected the teeth and analyzed them at the Laboratory of Life and Environment Co, Ltd.

The neuropsychological test data were collected from the adult group using Standard Progressive Matrices (SPM) and the child group by Color Progressive Matrices (CPM). One hour tests were performed and the scores were transformed into the Wechsler Scale.

Specific questionnaires were designed in order to collect demographic data, health behavior and possible adverse health effects.

Data analysis

The data were analyzed using descriptive statistics. Means, standard deviation, frequency and percent distribution were used to describe the demographic characteristics of the study population for the village, adverse health effects, concentration of lead in environmental/ biological samples, and IQ scores. The *t*-test was applied to compare mean independent variables in the two groups (exposed and non-exposed). The one way ANOVA was applied to compare the mean scores of more than two groups of variables (blood lead levels, tooth lead levels, IQ scores, hematocrits, and ages) in the exposed and non-exposed areas. A correlation was used to show a negative relationship between blood lead levels, tooth lead levels and IQ scores. Relative Risk was used to assess health risk between the exposed and non-exposed groups. Multiple regression analysis was used to predict whether risk factors affected short-term lead exposure and long-term lead exposure (cumulative exposure).

RESULTS

General information

Sixty-seven point eight percent of the exposed group were males and 42.2% were females. Sixty-six percent of the exposed group were less than 15 years old and 34.1% were between 15 and 65 years old. All the exposed group lived less than 30 km from lead mining. Forty-one point three percent of the non-exposed group were males and 58.8% were females. Forty-six point three percent of the non-exposed group were less than 15 years old and 53.8% were 15 to 65 years old. All the non-exposed group lived more than 30 km from lead mining.

Health behavior and adverse health effects

Most of the exposed group smoked and drank alcohol. Drinking water, food preparation water, and personal cleaning used water from the mountain. Eighteen percent used water from the creek. All the exposed group were less than 15 years old, and sometimes swam in the creek. Each household cooked at home, the materials being from natural sources or farming. The main foods of the exposed group were fish from the creek, vegetables planted in the village, and chicken, duck, and pork raised in the village. Most of the non-exposed group were non-smokers and non-alcohol drinkers. Drinking water, food preparation water and personal cleaning used tap water from the village. None of the respondents less than 15 years old swam in the creek. Each household cooked at home using materials from either natural sources or bought at the market. Most of the exposed group had illness (96.3%). The symptoms included anorexia, nausea, vomiting, abdominal pain, constipation, short concentration, muscle pain, headache, insomnia, and memory loss. In the non-exposed group, 13.8% had illness which included constipation.

Lead concentration in the environment

Soil, drinking and non-drinking water, air, vegetables, and meat were collected at 3 locations in each of the 6 villages. Eighteen samples of soil, drinking and non-drinking water, air, vegetables, and meat were obtained from Klity Bon, Klity Lang, Huay Suea, Ti Pu Yeh, Kreung Krawier, and Tha Din Daeng. Laboratory analysis showed the soil, vegetables, and meat had lead concentrations above the standard of the Ministry of Public Health. All soil samples from the 6 villages had lead levels above standard. There were five vegetable samples (mint, bitter gourd, Chinese watercress, basil, and turmeric) from Klity Lang, Klity Bon, Huay Suea and Ti Pu Yeh, with lead levels above standard. The fish and shell fish from Klity Lang and Ti Pu Yeh had lead levels above standard (Table 1).

The standards of the Ministry of Public Health for lead levels in soil, water, air, vegetables, and meat are 55 mg/kg, 0.03 mg/l,

Table 1
Lead levels in soil, water, air, vegetables and meat in exposed and non-exposed areas.

Sample (Unit)	Lead concentration					
	Klity Bon	Klity Lang	Huay Suea	Ti Pu Yeh	Kreung Krawier	Tha Din Daeng
Soil (mg/kg)	598.7	153.3	738.3	98.7	106	74
Water (mg/l)	0.00131	0.00173	0.00343	0.00052	0.00148	0.00045
Air (mg/m^3)	0.0022	0.0010	0.0071	0.0036	0.0032	0.0014
Vegetables(mg/kg)						
Mint	10	4.2	9.4	0	0	0
Bitter gourd	6.8	0	0.27	0	0	0
Chinese water cress	3.2	0	0	0	0	0
Basil	0	6.6	0	0	0	0
Turmeric	0	0	0	1.9	0	0
Other vegetables[a]	0	0	0	0	0	0
Meat (mg/kg)						
Fish	0	19	0	0	0	0
Shell fish	0	0	0	3.3	0	0
Chicken and pork	0	0	0	0	0	0

[a]Other vegatables=pumpkin, bitter gourdy, canton, lemon grass, chilli, rice, Thai peper coriander and egg plant.

Table 2
Percent distribution of blood and tooth lead levels and IQ scores in exposed and non-exposed groups.

Item	Exposed group No. =135%	Non-exposed group No. = 80%
Blood lead levels		
High (>10 µg/dl)	98 (72.6)	0 (0)
Low (<10 µg/dl)	37 (27.4)	80 (100)
Tooth lead levels		
High (>10 µg/g)	46 (34.1)	0 (0)
Low (<10 µg/g)	89 (65.9)	80 (100)
IQ scores		
High (>90)	11 (8.1)	76 (95.0)
Low (<90)	124 (91.9)	4 (5.0)

0.02 mg/m^3,1 mg/kg, and 1 mg/kg , respectively.

Blood and tooth lead levels in the exposed and non-exposed groups

In the exposed group, 89 children and 9 adults (98 villagers) had blood lead levels higher than 10 µg/dl and 40 µg/dl, respectively, which total 72.6%. Forty-two children and 4 adults (46 villagers) had tooth lead levels higher than 10 µg/g and 40 µg/g, respectively, which total 34.1%. One hundred twenty-four people in the exposed group (91.9%) had IQ scores lower than 90 (Table 2).

The comparision of mean blood and tooth lead levels and IQ scores between exposed and non-exposed groups

The age and IQ scores in the exposed group were statistically lower than the non-exposed group ($p<0.001$). The average blood lead level, tooth lead level and hematocrit of the exposed group were statistically higher than the non-exposed group ($p<0.001$) (Table 3).

The risk effect to IQ scores in the exposed and non-exposed groups by age

Eighty-one villagers in the exposed group (91.0%) who lived near the lead mine exposure area, had IQ levels lower than average, while the non-exposed group had IQ scores higher than average. The risk of having a low IQ in the exposed group (children) was 5.6 times greater than the non-exposed group ($p<0.001$). The risk of low IQ scores in the exposed groups, ages 15-30, 31-40, and 41-

Table 3
Comparision of mean blood lead levels, tooth lead levels and IQ scores between the exposed and non-exposed groups.

Variable / Age-range	Group	N	$\bar{X}$	SD	Std error mean	p-value
Age						
6-65 years old	Exposed	135	19.3	15.8	1.4	0.001
	Non-exposed	80	27.3	19.3	2.2	
Hematocrit						
6-65 years old	Exposed	135	35.3	3.1	0.3	0.001
	Non-exposed	80	37.4	3.8	0.4	
<15	Exposed	89	34.06	1.89		<0.001
	Non-exposed	37	36.17	3.39		
15-30	Exposed	16	35.00	35.00		<0.001
	Non-exposed	1	37.88	-		
31-40	Exposed	11	39.67	4.18		<0.001
	Non-exposed	6	40.46	4.76		
41-65	Exposed	19	38.17	2.40		<0.05
	Non-exposed	6	40.68	2.69		
Blood lead level						
6-65 years old	Exposed	135	28.0	13.4	1.2	<0.001
	Non-Exposed	80	6.5	1.8	0.3	
<15	Exposed	89	25.75	13.89		<0.001
	Non-Exposed	37	6.74	1.65		
15-30	Exposed	16	36.81	11.81		<0.001
	Non-Exposed	1	7.00	-		
31-40	Exposed	11	28.09	9.05		<0.001
	Non-Exposed	6	5.50	1.38		
41-65	Exposed	19	31.37	11.34		<0.001
	Non-Exposed	6	6.00	2.76		
Tooth lead levels						
6-65 years old	Exposed	135	15.20	15.30	1.3	<0.001
	Non-Exposed	80	8.10	1.70	0.2	
<15	Exposed	89	13.96	14.37		<0.001
	Non-Exposed	37	7.68	2.00		
15-30	Exposed	16	20.00	19.76		<0.024
	Non-Exposed	7	7.51	1.50		
31-40	Exposed	11	14.16	9.57		<0.010
	Non-Exposed	13	8.28	1.24		
41-65	Exposed	19	17.22	17.96		<0.05
	Non-Exposed	23	8.92	1.16		
IQ scores						
6-65 years old	Exposed	135	81.50	8.20	0.7	<0.001
	Non-Exposed	80	96.10	7.20	0.8	
<15	Exposed	89	82.70	8.27		<0.001
	Non-Exposed	37	96.14	7.80		
15-30	Exposed	16	81.94	7.37		<0.001
	Non-Exposed	7	101.14	6.47		
31-40	Exposed	11	81.80	7.94		<0.001
	Non-Exposed	13	99.00	6.86		
41-65	Exposed	19	75.42	5.99		<0.001
	Non-Exposed	23	92.78	5.09		

Table 4
Effect on IQ in the exposed and non-exposed groups.

Group / Area	Total number	No with low IQ	% with low IQ	RR	95% CI	p-value
Less than 15 years old						
Exposed	89	81	91.0	5.63	3.00-10.54	<0.001
Non-exposed	37	0	0	-		
15-30 years old						
Exposed	16	14	87.5	4.50	1.33-15.28	<0.001
Non-exposed	7	0	0	-		
31-40 years old						
Exposed	11	10	90.9	14.00	2.12-92.55	<0.001
Non-exposed	13	0		-		
41-65 years old						
Exposed	19	19	100	14.00	2.38-142.85	<0.001
Non-exposed	23	4	17.4	1.00		

Table 5
Association between IQ scores, blood lead levels, and tooth lead levels in the exposed and non-exposed groups.

Group	r	p-value
Less than 15 years old		
Blood lead level	-0.397	<0.001
Tooth lead level	-0.129	<0.001
15-30 years old		
Blood lead level	-0.359	<0.001
Tooth lead level	-0.385	<0.005
31-40 years old		
Blood lead level	-0.710	<0.001
Tooth lead level	-0.249	<0.005
41-65 years old		
Blood lead level	-0.600	<0.002
Tooth lead level	-0.282	<0.005

65 years old, were 4.5, 14.0, and 14.0 times those of the non-exposed group, respectively (p<0.001) (Table 4).

Correlation between IQ scores and blood and tooth lead levels in the exposed and non-exposed groups

The WISC-IQ scores in the exposed group less than 15 years old had a negative correlation with blood and tooth lead levels (r = 0.397 and 0.129 with p<0.001). The exposed group (children) who had high blood and tooth lead levels tended to have low IQ scores. The WAIS-IQ scores of the adult villagers in each age group of the exposed group had a negative correlation with blood and tooth lead levels. The IQ scores of the exposed group members ages 15-30, 31-40, and 41-65 years old had a negative correlation with blood and tooth lead levels (r = 0.359, 0.385, 0.710, 0.249, 0.600, 0.282, respectively, with p<0.05) (Table 5).

DISCUSSION

This study showed that most of the villagers in risk and non-risk areas were less than 14 years old. The lead exposed groups had higher blood and tooth lead levels; 96.3% of the number of the exposed group had symptoms. Landrigan (1994) stated that children were the group most exposed and most sensitive to the toxic effects of lead. Developing children and aldolescents were more sensitive to lead toxicity than adults. Children living in the vicinity of lead-emitting factories and children whose parents worked in lead plants revealed evidence of increased lead absorption

(Rom, 1983). The children living near the lead works had significantly higher blood lead levels than children living further away (Lansdown *et al,* 1974). Klity villagers were exposed to lead as a result of their lifestyle. They were farmers who consumed their own products. Furthermore, soil and creek water utilization increased their chances of getting lead contamination from the food chain. The findings of this study are consistent with the study of Healy and Aslam (1981) and Smith *et al* (1983) which reported that agriculture crops growing near a source of lead have significantly higher concentrations of lead deposited on them. Consuming contaminated vegetables or fruit or meat from farm animals grazing on polluted grass can result in a considerable body burden of lead.

Lead adversely affects many body systems; the most sensitive are nervous system, which includes the central nervous system and peripheral nervous system (Landrigan, 1994). The subclinical effects on the central nervous system were the most common effects, which resulted in cognitive impairment measured by Intelligence Quotient (IQ) tests (Pocock *et al*, 1994). The average IQ level in 64 children living in the high lead area was 86.64±9.68 with 40 children (62.5%) being less than normal level. In comparison with the other group, the average IQ level was 91.98±10.26 with 24 of children (37.5%) being higher than the normal level. The results show that the IQ level in children living in a high-lead area was significantly lower than that of children living in a low-lead area ($p<0.003$) (Mahram, 2004). This study is consistent with the study of Fulton *et al* (1987) which reported that children with high lead levels scored lower on the Wechsler Intelligence Scales of Children (WISC) IQ test than children with lower lead levels. A study of Chinese children reported a significant dose-response relationship between blood-lead concentration (about 10 µg/dl) and IQ scores. There is evidence that increasing lead levels are associated with a greater impacts on IQ (Pocock *et al,* 1989; Raab *et al,* 1989).

Klity creek was contaminated by lead in the year 1998. Tooth specimen collection was conducted in the years 2001-2002 and it was found that all children who had teeth lead levels over 10 µg/g had high blood lead levels. High blood lead level were associated with high tooth lead levels. Forty-two of 89 cases (47.2%) of exposed children with high tooth lead levels, and 4 of 9 cases (44.4%) in adults with high lead levels had evidence of lead absorption in both the blood stream and teeth. This may be due to industrial and mining activities releasing lead and lead compounds into the soil or creek water. Local community members or Klity villagers were exposed to emission from these sources through ingestion of lead contaminated soil or water. The US Center for Disease Control and Prevention (CDC, 1997) has set standards for lead: a level of concern for children is 10 µg/dl and a cause for medical examination is 40 µg/dl. One study report lead absorption in the gastrointestinal tract is substantially greater in children (about 50%), compared to adults (10%) (Ziegler *et al,* 1978). The non-excreted fraction of absorbed lead is distributed among three compartments: blood, soft tissue and the mineralizing tissue (bones and teeth). The biological half-life of lead in blood and soft tissue can be as short as 28 to 40 days. Bone and tooth lead has a half-life in years (Barry and Mossman, 1981; O'Flaherty *et al,* 1982; Kang *et al,* 1983). Consequently, a blood lead level is the main index of lead exposure. The bone lead level is a biologic marker of cumulative lead exposure over many years and may better predict the effects of lead toxicity that arise from chronic low to moderate exposure.

The non-exposed group had blood and teeth lead levels not over the standard level and IQ scores averaged higher than 90. In the group exposed to lead, IQ scores were lower than 90 and blood and tooth lead levels were over the standard level. These adult groups were periodically employed men who had been directly exposed to lead in the workplace with a history of working a lead mine. They were interviewed but were not working because the mine was closed. They had lead contamination, which affected their IQ score. Intelligence Quotient (IQ) measures were identified to represent the adverse health effects resulting from lead exposure. Some medical research in large groups of children with blood lead levels of approximately 10 µg/dl included impairment of the central nervous system and reduction of mental abilities. Adverse effects noted in these population studies of children with blood lead levels less than 25 µg/dl noted lower IQ levels and abnormal cognitive development and behavior in pre-school as well as in schoolchildren.

Neurological deficits associated with exposure to lead in early childhood, may persist into late adolescence. Studies of groups of children exposed to chronic high lead levels in early childhood found children have increased chances of poor performance at school, including reading disabilities. Children with increasing dentine (teeth) lead levels in pre-school years, who were followed up until adolescence, were seven times more likely to drop out of high school. In young adults impairment was found in neurobehavioral functioning with lower IQ scores, which were inversely related to higher dentine lead levels. (Needleman and Gastonis, 1990). Bergomi *et al* (1989) studied 237 schoolchildren in a lead-polluted industrial area in northern Italy to assess the relationship between various biological indicators (lead in blood and teeth) and some neuropsychological functions, assessed by a battery of five psychometric tests. Mc Michael *et al* (1994) studied the relation between lead concentration in deciduous central upper incisor teeth and intellectual functioning in 262 children who were followed from birth to age 7 years in the lead smelter town of Port Pirie, South Australia. IQ was estimated using Wechsler Intelligence Scale for Children (WISC-R). There was an inverse relation between tooth lead concentration and intellectual development. IQ declined by 2.6 points for each interval-log unit increase in tooth lead concentration. Similarly, some studies have found that for every 10 µg/dl increase in blood lead level, children's IQ dropped by 4-7 points (Yule *et al,* 1981; Schroeder *et al,* 1985; Hawk *et al.* 1986; Landsdown *et al,* 1986; Fulton *et al,* 1987; Winneke *et al,* 1990; Canfield *et al*, 2003).

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