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Options for Monitoring
Biological and Environmental Lead During
the Phase-out of Lead in Gasoline
in Latin America & the Caribbean

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by
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PREFACE

Declaration 23 of the Plan of Action of the Summit of the Americas (Miami, Florida, December 9-11, 1994) first established a hemispheric Partnership for Pollution Prevention. In November 1995, a meeting of country technical experts was held in Puerto Rico to further structure the Partnership and to specify initial activities to be undertaken. As a result, the partner governments committed themselves to develop and implement national action plans to phase out the use of lead in gasoline as rapidly as possible.

To provide technical assistance in meeting this goal, a task force of international and national agencies was created under the leadership of the World Bank. The task force advises the World Bank in its efforts to lay out and coordinate a comprehensive program of joint support to encourage the phase-out of leaded gasoline in Latin America and the Caribbean (LAC). This report is one of several tools developed at the request of the task force. It is the result of collaborative effort among USAID s Environmental Health Project, the Pan American Health Organization/World Health Organization (PAHO/WHO), and the World Bank, and is funded by the Environmental Initiative of the Americas (EIA) and the Hemispheric Free Trade Expansion (HFTE) project of USAID s Bureau for Latin America and the Caribbean and the USAID Global Bureau s Centers for Environment and Population/Health/ Nutrition.

The phase-out of leaded gasoline potentially affects trade in three ways. First, it could promote the wider use of catalytic converters in new cars sold in LAC. Second, countries that produce unleaded gasoline can expect to see increased gasoline export sales. Third, the increased use of substitutes for lead in gasoline could affect trade in octane enhancers and oxygenators.

This report provides a description of methodologies for biological and environmental monitoring for lead during the phase-out of lead in gasoline in Latin America and the Caribbean, options which can be adapted and used throughout the LAC region.

ABOUT THE AUTHORS

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ACRONYMS

ALA-D	gamma-aminolevulinic acid dehydratase
ANOVA	analysis of variance
ARPEL	Asistencia Recítroca Petrolera Emtresarial Latinoamericana (Reciprocal Assistance of Latin American Oil Companies)
ASV	anodic stripping voltametry
BLL	blood lead level
CCHAC	Committee for Cooperation on Hydrocarbons in Central America
CDC	U.S. Centers for Disease Control and Prevention
CEDI	Caribbean Environment and Development Institute
CIDA	Canadian International Development Agency
EIA	Environmental Initiative of the Americas
EHP	Environmental Health Project
ELPAT	Environmental Lead Proficiency Analytical Testing Program
EPA	U.S. Environmental Protection Agency
FIOCRUZ	Fundacão Oswaldo Cruz
GFAAS	graphite furnace atomic absorption spectrometry
HFTE	Hemispheric Free Trade Expansion (USAID project)
LAC	Latin America and Caribbean region (also a Bureau in USAID)
NHANES	U.S. National Health and Nutrition Examination Survey
NIOSH	U.S. National Institute of Occupational Safety and Health
OLADE	Organización Latinoamericana de Energía (Latin American Organization for Energy)
OSHA	Occupational Safety and Health Administration
PAHO	Pan American Health Organization

PAT	Proficiency Analytical Testing program
PPP	Partnership for Pollution Prevention (1994 accord)
SAS	Commercial software program for statistical analysis
SD	standard deviation
SYSTAT	Commercial software program for statistical analysis
TSP	total suspended particulate
UPC	urinary coproporphyrin
USAID	U.S. Agency for International Development
WHO	World Health Organization
ZPP	zinc protoporphyrin

Scientific Measurements and Units

m^3	cubic meters
PM_{10}	particulate matter less than or equal to 10 micrometers in diameter
$\mu g/dL$	micrograms per deciliter

EXECUTIVE SUMMARY

Background

The use of leaded gasoline results in lead emissions from vehicles, and this contributes significantly to urban environmental degradation in Latin America and the Caribbean (LAC). In the United States, leaded gasoline has been identified as a significant contributor to the cumulative lead burden of high-risk human populations, particularly children and women of child-bearing age in urban areas (NAS 1993; Pirkle et al. 1994). Studies conducted in several countries suggest that measurable problems in learning can be detected in children whose median or average blood lead levels are as low as 5 to 10 μg/dL (IPCS 1995; Needleman and Gastonis 1990; Schwartz 1994). Cumulative lead burdens in adults are also linked to neurological and physiological problems such as increased hypertension (Payton et al. 1998; Hu et al. 1996b) and associated renal and cardiovascular disease (Kim et al. 1996; Schwartz 1995).

Chronic lead poisoning is suspected as a health problem affecting many children and adults in the LAC region. Published information on blood lead levels in children and adults and lead in the environment has been limited, though more information has recently become available (Howson et al. 1996; Lacasaña et al. 1996). Despite limited information, lead intoxication is recognized as one of the major public health problems in some countries of the region.

Approach

This report describes methodologies for monitoring blood lead levels during the phase-out of lead in gasoline at the national level. The proposal focuses on particular segments of the general population, chosen because their health (or that of their offspring) is strongly impacted by exposure to lead and because they are more readily accessible at schools, workplaces, and hospitals. In addition, it is suggested that environmental monitoring be conducted in parallel, by periodic assessment of leaded gasoline use or sampling for lead in air.

Issues for Consideration

An important aspect in carrying out these monitoring options is the requirement that the options be implemented in the context of existing programs and with current facilities in the LAC region. Monitoring should be incorporated into an existing health institution s activities or within the context of a university-based research group. The institutional locus of monitoring should be flexible, accounting for differing capabilities from country to country.

In addition, those undertaking blood lead monitoring programs need to be prepared for the discovery of important sources of lead exposure other than leaded gasoline. As demonstrated by the case study in Peru (see section 2.5 in Chapter 2), blood lead monitoring programs often reveal other sources of lead exposure. If these other sources of exposure are significant, from a public health point of view, follow up with study participants will be required and, potentially, interventions to reduce these other sources of exposure will be needed.

PART A: OVERVIEW

1 INTRODUCTION

1.1 Health Effects from Lead Exposure

In the United States, emissions from vehicles using leaded gasoline have been identified as a significant contributor to the cumulative lead burden of sensitive human populations, particularly children and women of child-bearing age in urban areas (NAS 1993; Pirkle et al. 1994). Studies conducted in several countries suggest that measurable problems in learning can be detected in children whose median or average blood lead levels are as low as 5 to 10 μg/dL (IPCS 1995; Needleman and Gastonis 1990; Schwartz 1994). These adverse health effects are illustrated in Figure 1.

In recent years, researchers have reported extensively on the developmental and neuropsychological effects of lead in children (Calderón-Salinas et al. 1996; Pocock et al. 1987; see Banks et al. 1997 for a review). Groups of children with high lead levels have been shown to have lower scores on IQ tests, and researchers have also accumulated data to suggest that blood lead levels are inversely related to cognitive function and ability (Bentou-Maranditou et al. 1988; Hansen et al. 1989; PAHO 1990a and b; Damm et al. 1993). Associations between body lead levels and neuroconductivity have also been reported by Fergusson et al. (1993), Grandjean et al. (1991), and Stiles and Bellinger (1993). Motor-visual integration effects of lead have been reported by Baghurst et al. (1995) and Bellinger (1995) and behavioral problems as reported by teachers and parents, have been cited by Silva et al. (1988).

Additionally, Muñoz et al. (1993) examined neurocognitive developmental capacity in children in Mexico City with chronic lead exposures. The results showed that blood lead levels were a strong predictor for lower performance on full-scale IQ as measured by a version of the Weschler Intelligence Scale for Children, as well as lower scores on other measures of school performance. The average blood lead levels exceeded 19 μg/dL and that the major sources of exposure were vehicular traffic near the child s residence, use of glazed pots for preparing and storing food or juices, and frequency of chewing pencils.

The current level of concern for adverse developmental effects in children is 10 μg/dL, established by the U.S. Centers for Disease Control and Prevention (CDC 1991) and other national and international health authorities (e.g., French Academy of Pediatrics; Australian Medical Research Council; Health and Welfare Canada; World Health Organization/Pan American Health Organization).

Figure 1
Effects of Inorganic Lead on Children and Adults:
Lowest Observable Adverse Health Effects

CHILDREN	Lead Concentration in Blood (μg Pb/dL)	ADULTS
Death →	150	
	100	← Encephalopathy
Encephalopathy →		← Frank anemia
Nephropathy →		
Frank anemia →		← Decreased longevity
Colic →		
	50	← ⇓Hemoglobin synthesis
⇓Hemoglobin synthesis →		← Ú Peripheral neuropathies ³ Infertility ♂ À Nephropathy
	40	
⇓Vitamin D metabolism →		← Ú ⇑Systolic blood pressure ♂ ³ À ⇓Hearing acuity
	30	
		← ⇑Erythrocyte protoporphyrin ♂
⇓Nerve conduction velocity →		
⇑Erythrocyte protoporphyrin ¿ ³ → ⇓Vitamin D metabolism (?) Ù	20	← ⇑Erythrocyte protoporphyrin ♀
Developmental Toxicity →		
		← ⇑Hypertension (?)
⇓IQ, ⇓Hearing, ⇓ Growth →		
Transplacental Transfer →	10	

⇑ Increased Function ⇓ Decreased Function

Source: ATSDR 1992. In Howson et al. 1996. *Lead in the Americas*.

Cumulative lead burdens in adults are also linked to neurological (Payton et al. 1998) and physiological problems such as increased hypertension (Hu et al. 1996b) and associated renal and cardiovascular disease (Kim et al. 1996; Schwartz 1995).

Chronic lead poisoning is suspected as a health problem affecting many children and adults in the Latin American and Caribbean (LAC) region. Historically, published information on blood lead levels in children and adults and lead in the environment in this region has been limited but, recently, more data has been published (Howson et al. 1996; Lacasaña et al. 1996). (See Table 1 for a review of recently published studies.) Despite limited information, some LAC countries have recognized lead intoxication as one of the major public health problems. In Mexico, for example, leaded gasoline has been reported as one of the contributors to high blood lead levels in children (Romieu et al. 1990; Rothenberg et al. 1998). Other major sources of lead exposure identified in urban environments in the LAC region include air particulates and industrial waste from lead-acid battery recycling (Vahter et al. 1997; Bonilla et al. 1998), pencils coated with lead-paint (Olaiz et al. 1996a), consumption of canned foods containing lead solder, household plumbing and water storage tanks, and use of lead-glazed ceramics used for food preparation and storage (Romieu et al. 1994; Romieu et al. 1995). In addition, populations living in close proximity to smelting and mining operations are also at risk of lead exposure (Calderón-Salinas et al. 1996; Ordoñez et al. 1976).

1.2 Experience Monitoring Lead Levels

Monitoring changes in lead levels in human populations has allowed environmental health scientists to present evidence that environmental interventions are successful in reducing exposure as shown by declines in blood lead levels. One major intervention used in Mexico, the United States, and other countries in the Americas has been to eliminate lead from gasoline.

In the Americas, no country has a continuous, nationwide monitoring program for biological lead. However, the periodic U.S. National Health and Nutritional Examination Surveys (NHANES) helped track changes in blood lead levels among a representative sampling of 27,801 children and adults in the United States from the 1970s through the 1980s, the period in which the phase-out of leaded gasoline occurred. These studies have reported a significant lowering of blood lead levels among the general population (Annest 1983; Pirkle et al. 1994) associated with the phase out of leaded gasoline. By 1991-1994, the Phase 2 NHANES study estimated that only 4.4% of children 1-5 years in the United States had blood lead levels ≥ 10 μg/dL (CDC 1997). A monitoring study of the long-term trend (1974-1988) in blood lead levels among children in a large U.S. city (Chicago) and its relationship to air lead levels found that median blood lead levels had declined from 30 μg/dL in 1968 to 12 μg/dL in 1988, and were strongly associated with declining average air lead levels ($r = 0.8$, $p < 0.001$) from 1974 through 1988; most of the decline was attributed to the phase-out of leaded gasoline in Chicago during this period (Hayes et al. 1994).

Table 1
Recently Published Studies Describing Blood Lead Levels among Selected Populations in Latin America and the Caribbean

Author and year of publication	City and country	Age group (years)	Population studied	Sample size	Sources of exposure identified	Mean Blood Lead Level (µg/dL)
	Villa Venezuela, Nicaragua	1-14 years	Children	30	Air lead	7.4
Bonilla et al. [1998]	Managua, Nicaragua	6 months to 13 years	Children	97	Living close to a battery factory	17.2
Vahter et al. [1997]	Rural communities, Ecuador	4-15	Children	82	Recycling of batteries	52.6
Schutz et al. [1997]	Montevideo, Uruguay	2-14	Children	96	Exposure to traffic	9.5
Lopez-Carrillo et al. [1996]		1-5	Children	603	Ambient air Lead glazed ceramics	15.0
Romieu et al. [1995]		1-5	Children	200	Ambient air Lead glazed ceramics	9.9
Hernández-Avila et al. [1997]		At birth	Children	1,849	Ambient air Lead glazed ceramics	7.1
Farias et al. [1996]		13-43	Pregnant women	513	Ambient air Lead glazed ceramics	11.08
Rothenberg et al. [1998]	Mexico City, Mexico	6-18 months	Children	104	Lead in gasoline Lead-glazed ceramics	
	Lima, Peru					26.9
	Huancayo, Peru					22.4
	La Oroya, Peru					34.8
Ramirez et al. [1997]	Yaupi, Peru	18-50	Adults	320	Degree of industrialization	14.0
Jacoby [1998]	Lima, Peru	1-4	Children	40	Not mentioned	11.7
		At birth				2.99
	Santiago, Chile	24 months		312	Ambient air	5.04
		At birth			Paint Hand/Mouth Behavior	1.99
Frenz et al. [1997]	San Felipe, Chile (rural area)	24 months	Children	113	Living in Santiago	3.65

In Europe, the results of monitoring experiences in Budapest, Hungary, provide similar findings. Hungary is a medium-income country, like many in Latin America. Periodic monitoring of both environmental and blood lead levels has been performed. Airborne lead in the city declined from a mean of 3.0 $\mu g/m^3$ in 1985 to a mean of 0.6 $\mu g/m^3$ in 1993. The mean blood lead level in Budapest s children in 1985 was 24.8 $\mu g/dL$; by 1993 it had dropped to 7.6 $\mu g/dL$. In the same period (1985-1993), the lead content of gasoline was gradually reduced from 0.7 g/liter to 0.15 g/liter (Lovei 1996).

In Mexico, prior to the 1992 phase-out of lead in gasoline in Mexico City, a 1980 study reported the median blood lead levels of a cohort of 85 adult schoolteachers was 24 $\mu g/dL$ (AECLP/EDF 1994). Periodic monitoring in the Metropolitan Zone of Mexico City since 1991, however, has found that blood lead levels in the general population have decreased (Romieu and Lacasaña 1996). Elevated blood lead levels were also confirmed in a hospital-based study conducted in Mexico City (1991-92). Average blood lead levels among children were measured at 15.6 $\mu g/dL$ (Jimenez 1993). Currently, approximately 30 to 50% of the children are estimated to have blood lead levels exceeding 10 $\mu g/dL$ (Romieu and Lacasaña 1996).

It is estimated that 1,500 metric tons of lead were released into the air of Mexico City each year in the 1980s from the combustion of leaded gasoline alone (Contreras 1990). In the metropolitan area of Mexico City, ambient air monitoring carried out continuously since 1988 has documented a marked decrease in lead levels in ambient air, which in 1988 registered 1.95 $\mu g/m^3$ but by 1994 had dropped to 0.28 $\mu g/m^3$ (Howson et al. 1996; Romieu et al. 1992). Over the same period, a parallel decrease in blood lead levels in the residential population (i.e., referring to the general population, a mixture of adults and children) of the area was also documented (Driscoll et al. 1992; Romieu et al. 1994; Romieu and Lacasaña 1996; Rothenberg et al. 1998).

1.3 The World Bank Program to Support the Phase-out of Lead

The World Bank has recommended the phase-out of leaded gasoline worldwide, increased its interest in promoting investments to reduce the use of leaded gasoline in the LAC region (Lovei 1996), and secured co-funding from CIDA (the Canadian International Development Agency) to support these efforts. Initial work has focused on gathering existing information principally through ARPEL (a South American organization of state oil concerns), CCHAC (Committee for Cooperation on Hydrocarbons in Central America), and CEDI (the Caribbean Environment and Development Institute).

Overall, the Bank is developing seven tools for addressing the issue of lead risk reduction: 1) support for an inventory of gasoline use in the LAC region; 2) a study examining the health impacts of lead in gasoline and its alternatives; 3) development of monitoring options to describe trends in blood lead levels and environmental lead levels over time as leaded gasoline is eliminated throughout the LAC region; 4) the automobile industry and government studies summarizing the experience of older cars using unleaded gasoline; 5) the consequences for refineries switching to production of unleaded gasoline; 6) alternative fuels to gasoline; and (7) country-specific case studies of the conversion to unleaded automobile fuels. Figure 2 shows the seven World Bank tools for carrying out the leaded gasoline phase-out program. This paper represents options for the health monitoring tool.

1.4 Development of Monitoring Options

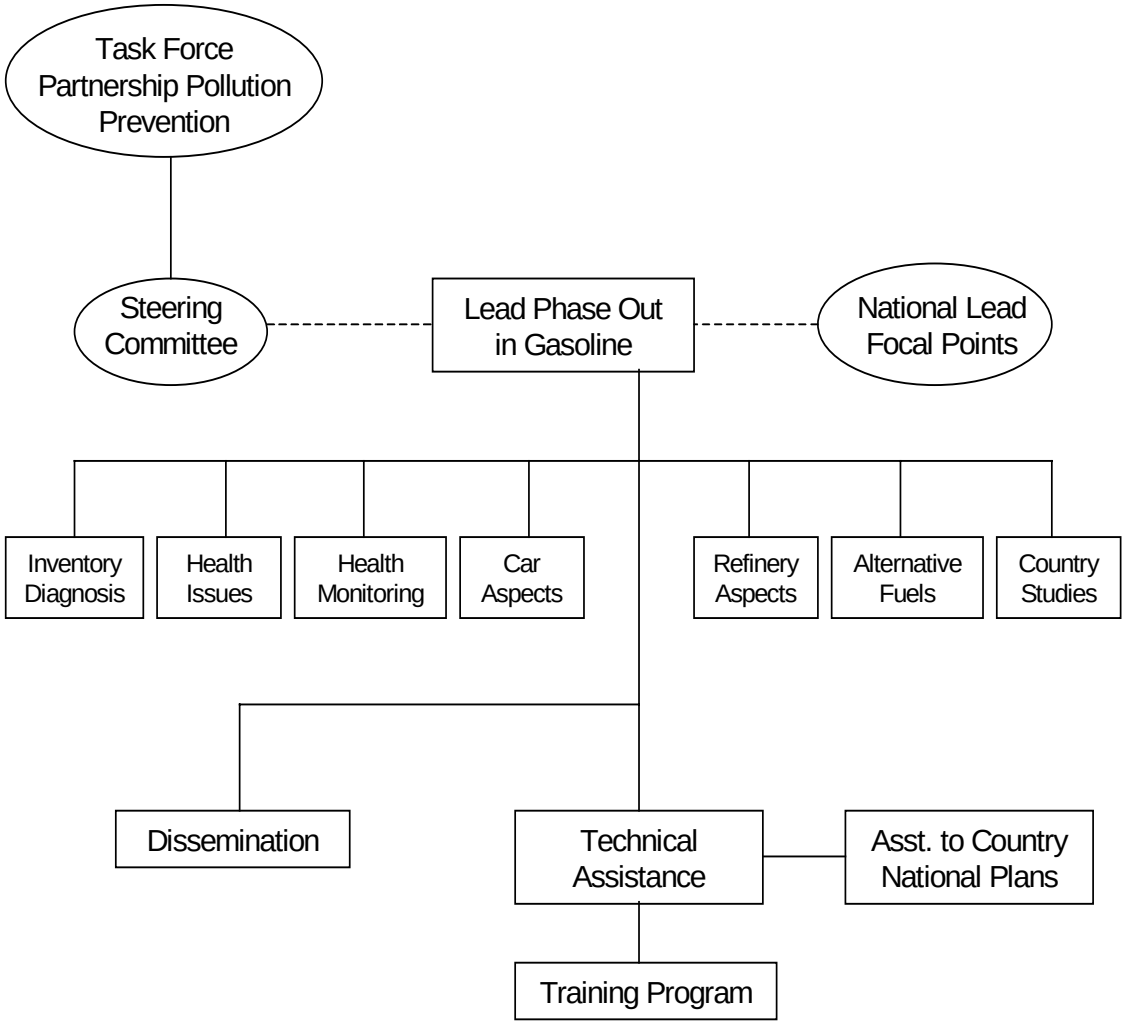
This report describes methods for tracking the changes in air lead levels and biological exposures to lead during the phase-out of lead in gasoline at either the national or municipal levels. The objective is to suggest monitoring options that can be adapted and used in countries throughout Latin America and the Caribbean region. The data generated can be used to aid policy-makers and health professionals in evaluating the impact of the phase-out of lead in gasoline.

The lead monitoring options will provide data to describe trends in measured blood lead levels in selected segments of the general population of the country, indirectly help identify other potential sources of lead that may impact blood lead levels, and help track changes in leaded gasoline use, as well as monitor levels of lead in urban air.

Although decreases in blood lead levels relative to the phasing of lead from gasoline have been documented in all age groups and various occupational groups, it is more efficient to focus on biological monitoring of three segments of the general population: worker populations occupationally exposed to leaded gasoline emissions, young urban children, and pregnant women at the time of delivery. These groups were chosen because their health (or that of their offspring is strongly impacted by exposure to lead and because they are readily accessible at schools, workplaces, and hospitals. It is also important that environmental monitoring be conducted in parallel with biological monitoring, through periodic assessment of leaded gasoline use or sampling for lead in air. It is recommended that biological and environmental monitoring be done annually, over a ten-year horizon, to inform program development and evaluation.

Both cost and infrastructure limitations prohibit the conduct of national population-based surveys in the region. However, targeting of these selected populations, representative sampling methods, and adequate sample sizes, will provide sound scientific information which can be used to inform policymakers and public health officials for decision-making purposes.

Figure 2
World Bank Gasoline Lead Phase-Out Project Organization



Source: Ing. Cor P. W. van der Sterren, Oil and Gas Division, Industry and Energy Department, World Bank.

2 TARGET POPULATIONS

The ultimate goal of monitoring blood lead levels is to identify trends over time as countries phase out the use of leaded gasoline. The proposed options call for monitoring selected groups in the population by collecting information through annual surveys of workers occupationally exposed to leaded gasoline, children, and umbilical cord blood from women at the time of delivery, along with environmental sampling of air and dust. Monitoring is proposed for urban areas where exposure to gasoline lead is likely the highest due to increasing numbers of automobiles.

2.1 Occupationally Exposed Adults

Workers occupationally exposed to lead in gasoline, i.e., bus and taxi drivers, traffic police, street vendors, and gasoline pump attendants, represent groups with the highest expected exposure to lead in air or from gasoline. Many studies evaluating these groups have documented high blood lead levels (see Table 2). In a recent study conducted in India (Potula and Hu 1996), three groups of workers (traffic police, bus drivers, and auto-body shop workers) exposed to leaded gasoline had blood lead levels ranging from 11 to 17 μg/dL, compared with the corresponding values of urban controls (office workers) who averaged 4.1 μg/dL.

By surveying adults with high exposure to lead in gasoline or air, it is possible to evaluate the impact of the reduction of lead in gasoline. However, among the many published studies that have reported changes in blood lead in relation to changes in lead content of gasoline, only one evaluated this change in occupationally exposed groups. The United Kingdom s (UK) Blood Lead Monitoring Program reported blood lead levels in a sample of traffic police between 1985 and 1986. The study group experienced an average decline in blood lead levels of 2.0 μg/dL, resulting from a decrease in the lead content of gasoline from 0.4 to 0.15 g/L. In contrast, concentrations fell less markedly in control groups of adults whose blood lead levels were slightly lower. Children monitored at the same time, however, showed similar declines as those observed in the police sample (Quinn and Delves 1989).

Previous studies of nongasoline-related lead-exposed worker populations have indicated elevated blood lead levels compared with the general population (Gittelman et al. 1994; Matte et al. 1991; Whelan et al. 1997; Aguilar-Madrid et al. 1999; Corzo and Naveda 1998). However, it is assumed that the impact of the phase-out of lead in gasoline will primarily affect only those who work in close proximity to gasoline-related lead sources.

Table 2
Studies That Have Evaluated Blood Lead Levels in Adults Occupationally Exposed to Lead in Gasoline

Authors	City	Exposure Group	Sample Size n	Mean Blood Lead Level (µg/dL)
Flindt et al. [1976]	Manchester, England	Taxi drivers	40	22.8
		Control		NA
Quinn et al. [1987]	Various cities, England	Police	175	11.3
		Control	195	10.9
Sharp et al. [1988]	San Francisco, USA	Bus drivers	342	6.4
		Control		NA
Jones et al. [1972]	London, England	Taxi drivers	50	28.7
		Control		NA
Khan et al. [1995]	Various cities, Pakistan	Transport workers	150	52.1
		Traffic Police	36	51.0
		Shop keepers in busy roads	36	52.1
		Control	36	24
Bossano and Oviedo [1996]	Quito, Ecuador	Street vendors	76	30.3
		Pregnant house wives (control)	83	18.4
Potula and Hu [1996]	Madras, India	Office worker (control	10	4.1
		Auto-shop worker	9	17.5
		Bus driver	22	12.1
		Traffic Police	88	11.2
Kapaki et al. [1998]	Athens, Greece	Bus Drivers	47	5.8
		Gas-station attendants	42	5.6
		Taxi drivers	47	5.9
		Control	33	5.7

NA = Not available in the reference

2.2 Children

Children are the most vulnerable segment of the population for health risks associated with lead exposure, because their systems absorb lead to a much greater extent than adults and their developing neurologic systems are more sensitive to lead exposure (Lovei 1995). In addition, children are typically moer exposed to lead in their environment due to frequent had to mouth contacts.

The evolution of our understanding of the dangers of lead to children has several benchmarks. At the end of the nineteenth century, lead was recognized as a poison to children where a clinical case series of children with high blood lead levels experienced concomitant symptoms of paralysis and ophthalmoplegia (Needleman 1988 and 1994). In the 1960s, development of biologic markers for low exposure levels and clinical identification of associated health effects increased our understanding of the adverse health effects associated with elevated blood lead levels.

Young children are known to absorb lead from the gastrointestinal tract more efficiently than do adults; it is estimated that children retain as much as 60% of ingested lead, while adults retain only about 5 to 10% (EPA 1986). In addition, children s higher respiratory rate and relative volumes of respiration (amount of air inhaled per unit of body weight) expose them to larger doses of airborne contaminants. And because children s brains are continuing to develop for the first six to eight years after birth, the brain cells of young children may be more sensitive to the long-lasting effects of lead on that organ (Silbergeld 1992).

One impediment to sampling children six months to six years (the target group for lead screening) has been difficulty in obtaining venous blood specimens. During recent years, researchers have found that capillary sampling or a finger stick a much less unpleasant and intimidating procedure may provide valid information regarding blood lead levels (Schlenker et al. 1994; Sargent 1996; Johnson 1997). The combination of finger stick sampling with new portable blood-lead detection devices that produce accurate results in the field within minutes have greatly enhanced the capability for blood lead testing. (The LeadCare system consists of a compact, hand-held, battery-powered instrument that requires no manual calibration. See Appendix E) These instruments have been used successfully in remote areas of Ecuador (Counter et al. 1998) and in Lima, Peru (see case study described in Section 2.5).

2.3 Pregnant Women at Time of Delivery

Because of intrauterine exposure of the fetus, pregnant women are an important high-risk population for the effects of lead. There is little inhibition of lead as it crosses the placenta, with exposure to the fetus documented as early as 12 to 14 weeks gestation (Buchet et al. 1978; Al-Saleh et al. 1995). Blood lead levels of women have been highly correlated with the blood lead levels of their developing fetuses and newborn infants; the mother s blood lead level can act as an early indicator of the adverse health effects that may accrue to a child during critical formative stages of development (Rabinowitz et al. 1991; Al-Saleh et al. 1995; Rothenberg et al. 1996).

Studies of umbilical cord blood lead levels have also been used as predictors of future neurologic and behavioral development of the fetus and, as some suggest, sentinels for environmental exposure to lead (Needleman et al. 1990; Schwartz 1994; Bellinger et al. 1994). These types of studies have been conducted in various countries, including the United States, Canada, Taiwan, Mexico, Venezuela, and Egypt (Harris 1972; Hu et al. 1996b; Troster and Schwartzman 1988; Clark 1977).

In the 1996 study in Mexico City, Rothenberg and coauthors examined the passage of lead from the pregnant mother to the unborn child. The mean maternal blood lead level was 8.4 μg/dL and the mean umbilical cord blood lead level was 7.4 μg/dL, indicating a high correlation between the maternal and cord lead levels ($r=.80$, $p< .0001$). The results of that study provided evidence to support the transfer of lead from the mother to the fetus. Such studies suggest that low levels of lead exposure to pregnant women may also be considered hazardous to the mother, resulting in

increased potential for sterility, abortion, stillbirths, and neonatal deaths. Furthermore, researchers have suggested that low levels of lead exposure *in utero* may be related to deficits in both fetal growth and postnatal behavior (Clark 1977). Bellinger et al. (1984, 1987) also reported neurobehavioral deficits on the Bayley Scale of Infant Development associated with higher prenatal exposures (cord blood lead levels of 10-25 μg/dL).

The skeleton is the primary storage site for approximately 95% of lead in the adult human body. Bone uptake of lead had been assumed to principally involve sequestration; however, significant amounts of bone lead may be released from bone into blood in response to the increased bone turnover associated with pregnancy. Recent studies (Gulson et al. 1997; 1998) with a lead isotope composition method have estimated that the skeletal contribution resulted in a mean increase of 31% in the $^{206}Pb/^{204}Pb$ ratio. Mobilization of bone lead has been raised as a concern for using umbilical cord blood lead levels to monitor environmental interventions. Because umbilical cord blood lead levels reflect the joint contribution of environmental (diet and air) and endogenous (skeletal lead) sources, any change in bone lead mobilization may mask the effect attributed to environmental interventions, such as decreasing lead from gasoline. However, since the half-life of lead in bone is on the order of decades, the contribution of this source in the absence of any pathological condition will remain constant over time and will not mask the effect of environmental interventions. Furthermore, several studies have shown that umbilical cord blood lead level fluctuates according to maternal environmental exposures. For example, during 1979 to 1981 umbilical cord blood lead levels among 11,837 deliveries recorded at the Boston Lying-In Hospital in Massachusetts varied significantly as the sale of leaded gasoline declined (Rabinowitz and Needleman 1983). In the same hospital, between 1980 and 1990, umbilical cord blood lead concentrations were reported to decrease from 6.6 μg/dL to 1.19 μg/dL, a change similar to the 76% decrease in blood lead levels measured in the United States general population between 1976 and 1991 (Pirkle et al. 1994; Hu et al. 1996a). These observations support the hypothesis that umbilical cord blood lead levels may be used as a sentinel marker to monitor the effects of phasing lead out from gasoline.

2.4 Monitoring Multiple Populations

It is important to target more than one group to compensate for confounding factors from other potential sources of lead. For example, children may be exposed through some unforeseen source in school or at home; if these sources changed concomitant to the change in the lead content of gasoline, this could mask the effect attributed to exposure from lead in gasoline. By monitoring children, persons occupationally exposed, and/or umbilical cord blood at time of delivery, confidence is increased that the effects of phasing out lead in gasoline will be detected in the general population.

The UK Blood Lead Monitoring Program, for example, targeted three different groups: adults in the general population, occupationally exposed groups (police and taxi drivers), and children six- to seven-years old attending primary schools situated on busy roads or congested crossroads. Declines in blood-lead concentrations were detected in all three groups; however, changes were more apparent in the occupationally exposed groups and in children (Quinn and Delves 1987). For a list of additional studies that have evaluated blood lead levels in occupationally exposed adults, see Table 2.

2.5 Case Study in Peru

As part of the activities related to removing lead from gasoline, the Peruvian government proposed the implementation of a blood lead survey to evaluate current levels of lead exposure in Lima and to obtain baseline data to monitor changes in blood lead associated with the phase-out of lead. The Directorate of Environmental Health (DEH) the environmental arm of the Ministry of Health was to carry out the study. An initial assessment revealed the following:

- Not much is known about lead exposure in Lima. Of the two studies available, one reported a mean blood lead level of 26.9 μg/dL among a sample of 80 adults, and the other reported a mean blood lead level of 11.7 μg/dL in 40 young children.

- DEH laboratories measured blood lead by flame atomic absorption spectrophotometry; no external quality controls were used and a 5 ml blood samples was required.

- The available budget hampered the possibility of conducting a random population-based survey of the entire Lima metropolitan area, or to update laboratory facilities to inlcude modern graphite furnace atomic absorption spectrometry.

As a result of this assessment and after discussion with key stakeholders, evaluators decided to sample pregnant women and first-grade children in Lima. Occupational groups exposed to lead from gasoline were not considered because initial consultations showed that these groups were somewhat reluctant to participate in the study, while school and hospital authorities were enthusiastic about the study. The availability of new technology for blood lead level determination battery-powered, portable anodic striping voltammeters (LeadCare portable instruments) resulted in a change in the method used to conduct the sampling. These portable instruments are the size of a hand calculator, are simple to use, require neither manual calibration nor refrigeration. DEH personnel received training in the use of these new instruments, which would allow them to obtain blood lead results within minutes, providing the opportunity to conduct on-site counseling; and to obtain blood samples by a finger-stick procedure that minimized external lead contamination (See Appendix E for a full protocol). Results of a pilot test documented a much higher acceptance rate of this sampling method among children and parents. This also caused evaluators to modify the study design to include children aged six months to seven years. In addition, because these instruments simplified field work, the sample was expanded to include more districts from Lima and Callao, a neighboring independent constitutional Province, that shares a large metropolitan area with Lima.

Between July 1998 and January 1999, DEH personnel sampled 2,510 children aged six months to nine years (mean age of 4.5 years) and 814 women in early postpartum living in Lima and Callao. The study population was selected through a sampling scheme that included government-operated schools, health centers, and public hospitals. Hospital-based recruitment (in five preselected maternity hospitals) was used as a strategy to increase the proportion of children aged 6 to 24 months and to sample women delivering babies. The survey included 16 schools (day-care centers and primary schools) located in areas of intense vehicular activity in five districts of Lima and Callao. Potential sources of lead were investigated with a small questionnaire about the most common sources of lead in the LAC region. Adverse health effects of lead exposure were evaluated using information regarding school performance and physical growth. All participants received information and counseling regarding their blood lead levels and written information indicating how to reduce exposure to lead.

The geometric mean blood lead level for the total population sampled was 9.9 μg/dL. Of the participating children, 29% had high blood lead levels (above 10 μg/dL) and 9.4% had blood lead levels higher than 20 μg/dL. Blood lead levels varied significantly by province. Compared with Lima, where evaluators observed a mean blood lead level of 7.1 μg/dL, Callao had a significantly higher mean blood lead level of 15.2 μg/dL. Variation in blood lead levels became more apparent when mean values were tabulated by school location. High blood lead levels were concentrated at schools in close proximity to a storage area for mineral concentrates. An additional investigation is underway to ascertain the impact of this storage area as a point source of lead exposure. Also, children reported to habitually put their hands in their mouths had higher blood lead levels.

Exposure to vehicular traffic was also associated with high blood lead levels. Children whose houses were on streets with high traffic had a twofold increase in the risk of having high blood lead levels. High blood lead levels were inversely associated with height and school performance.

Pregnant women who participated in the study had a mean age of 25 years. Their mean blood lead level was 3.5 μg/dL, and 2.4% (n=21) had blood lead levels over 10 μg/dL. The variance in blood lead levels at different recruitment hospitals reflected a positive trend, with higher mean blood lead levels at hospitals located in districts with higher vehicular traffic.

Results from this study are important in several ways. They provide valuable information regarding population blood lead levels and their determinants. The data also illustrate the application of an easy-to-use sampling technology to assess blood lead levels. This method provides a cost-effective alternative for countries that do not have the funds or technical expertise to develop laboratory facilities for blood lead testing based on atomic absorption. Results confirmed residents ubiquitous exposure to lead and suggest that reducing the use of leaded gasoline will reduce exposure to lead and its adverse consequences for future generations. As expected, the study also uncovered additional sources of lead. These findings emphasize the importance of implementing a comprehensive strategy for lead control, as opposed to a strategy that relies solely on the elimination of leaded gasoline to reduce exposure to lead. (This study is described in Hernández-Avila et al. 1999.)

3 APPROACHES TO MONITORING

3.1 General Considerations in the Design of Monitoring Options

Over the past 20 years numerous studies have monitored blood lead levels before and after decreasing the lead content of gasoline (see Table 3). Published reports vary substantially with respect to the studied populations, the sampling strategies, and the indicators used to assess changes in lead content. All but one study (Hinton D et al. 1986) provided substantial evidence that changes in the lead content of gasoline will reduce the lead burden of the population. This conclusion is not surprising, given that lead exposure from gasoline is ubiquitous, affecting almost all population groups, although at different intensities.

This chapter describes several different methods for monitoring the impact of the phase-out of lead in gasoline in the LAC region on lead exposure in the general population. Options include biological measurement of blood lead levels from children, occupationally exposed workers (e.g., traffic police, bus and taxi drivers, gasoline station pump attendants, or street vendors), and umbilical cord blood at the time of delivery. Additional monitoring options also include collection of information on environmental lead, which can be measured either by leaded gasoline use or by ambient air sampling.

The different approaches to monitoring the phase-out of leaded gasoline provide flexibility for a country, depending on the level of interest and resources available. Using various approaches also provides greater confidence in the findings. A theoretical framework which we have attempted to use in conceptualizing monitoring options consists of features described by Teutsch and Elliott (1994), that are considered critical to its success: 1) establishment of the monitoring option s objectives; 2) development of case definitions (e.g., CDC level of concern of 10 μg/dL blood lead level); 3) development of data collection mechanics; 4) development of data collection instruments; 5) field testing of methods; 6) testing of the analytic approach; 7) dissemination of information on monitoring protocols to all parties involved; 8) analysis and interpretation of findings; 9) system evaluation (providing answers to questions such as: Did the system generate needed answers to the problem?, was it helpful to policy planners and public health officials?, was it worth the effort?, what could be done to enhance the attributes of the system?).

A review panel consisting of lead experts from the region, government agencies, and academia contributed to the development of the approaches. (See Appendix A.) The panel proposed periodic surveys of one or more of the three selected sentinel populations, over a discrete timeframe (10 years) regarded as realistic for identifying and enlisting support of appropriate

Table 3
Summary of Studies Conducted before and after Reduction of Lead in Gasoline

Authors	Country	Years compared	Study design	Population studied	Change in lead in gasoline/air	Change in mean blood lead level (µg/dL)
Rabinowitz and Needleman [1983]	USA	1979-1981	Cross-sectional	Delivering women	$250*10^6$ gal per month to $75*10^6$ gal per month	Decline of 2.8 μg/dL per change of 10^8 g per month in leaded petrol sales
Maravelias et al. [1998]	Greece	1982-1996	Cross-sectional	Children	3.21 to 0.4 $\mu g/m^3$	-27.7 μg/dL
Hayes et al. [1994]	USA	1968-1988	Cross-sectional		0.9 to 0.1 $\mu g/m^3$	-18 μg/dL
Grobler [1992]	South Africa	1984-1990	Cross-sectional	Long distance runners	0.8 g/L to 0.4 g/L	-38.9 μg/dL
Quinn and Delves [1989]	England	1985-1986	Longitudinal and cross-sectional	Police	0.4 to 0.15 g/L	-2.0 μg/dL
				Children		-1.5 μg/dL
				General population		-1.0 μg/dL
Bono et al. [1995]	Italy	1985-1994	Cross-sectional	Adults, Blood donors	0.4 to 0.15 g/L	-8.5 μg/dL
Wang et al. [1997]	Canada	1982-1990	Cross-sectional	Children	2.6×10^9 to 1.9×10^7 g of lead per year	1.03 μg/dL per L per year
Rothenberg et al. [1998]	Mexico	1987-1993	Longitudinal	Children from birth to 36 months	Not reported	7.6 μg/dL
Weitlisbach et al. [1995]	Switzerland	1984-1993	Cross-sectional	Adults, general population	0.40 to 0.15 g/L	12.2 to 6.81 μg/dL
Hinton et al. [1986]	New Zealand	1978-1985	Cross-sectional	Adults (females)	No Change	11.5 to 6.8 μg/dL
				Preschool children		14.0 to 7.9 μg/dL
Taylor et al. [1995]	Australia	1993-1979	Cross-sectional	Children	3.3 $\mu g/m^3$ to 0.96 $\mu g/m^3$	11.1 to 5.7 μg/dL
Schuhmacher et al. [1996]	Tarragona, Spain	1990-1995	Cross-sectional	Adults	0.40 to 0.15 g/L	11.9 to 6.3 μg/dL
				Children		8.5 to 4.2 μg/dL
Maresky and Grobler [1993]	Capetown, South Africa	1984 1990	Cross-sectional	Adults	0.83 g/L to 0.4 g/L	9.7 to 7.2 μg/dL

agencies and gathering useful data. However, the appropriate length of time will depend on how rapidly lead phase-out policies are implemented.

3.2 Biological Monitoring

Biologic markers of lead exposure that have been used in surveys of children and adults include indicators of *internal dose* such as lead concentrations in blood, urine, feces, teeth (dentin), hair, and bone (Brody et al. 1994; Rabinowitz et al.1991; EPA 1986; Silbergeld 1991; Steenhout 1982); indicators of *biochemical change* including erythrocyte zinc protoporphyrin (ZPP) levels, which correlate well with lead exposure, ALA-D (gamma-aminolevulinic acid dehydratase), UPC (urinary coproporphyrin), hemoglobinemia, and stippled basophilic erythrocytes (Corey and Galvão 1989); *neurological indicators* such as electro-physiology (conduction velocity, evoked potential) and neuroconductivity (Howson et al. 1996); and *behavioral indicators* using neuropsychological and behavioral parameters (e.g., Baghurst et al. 1992, Bellinger and Dietrich 1994, Needleman et al. 1996, Rice 1996, Ruff et al. 1996).

The Global Environmental Monitoring System (GEMS) of the United Nations Environment Program has selected human hair as one of the materials for worldwide biological monitoring. Human nails and animal hair and nails have also been used to detect a variety of trace metals, including lead (EPA 1979). However, blood lead is the most common indicator used and has been the basis for most of the studies that have established the cause-and-effect relationships between lead exposure and health impacts. Hence, the monitoring options presented in this report use blood lead level as the biomarker of choice.

Biological (blood lead) and environmental (air lead) monitoring programs can use one or more of the following three options, based upon resource availability, logistics, and practicality. The advantages and disadvantages of each approach are discussed below and summarized in Table 4. Environmental lead sampling is also briefly discussed in this section and expanded upon in Chapter 7. It is important to note that environmental lead sampling is meant to complement but not replace the biological monitoring of human populations.

Option: Periodic Survey of Highly Exposed Occupational Populations

This approach would survey groups of workers (e.g., traffic police, bus or taxi drivers, street vendors, or gasoline station pump attendants) highly exposed to automobile emissions by inhalation and/or ingestion of particulates.

The advantage of the occupational option is that it targets individuals in the population with high exposures to leaded gasoline, which can be compared to a similar group (age-matched) not occupationally exposed (e.g., two cohorts of men aged 20-35). This approach minimizes the influence of other potential sources of lead exposure (confounders, i.e., other sources of exposure that may change during the evaluation period), which might mask a drop in blood lead level as a result of leaded gasoline elimination. By examining differences in blood lead levels of these two cohorts, it may be easier to evaluate the impact of reduced use of leaded gasoline and consequent impact in th population at large.

Table 4
Advantages and Disadvantages of Monitoring Options for Phase-out of Lead in Gasoline

Biological Monitoring

	Advantages	Disadvantages
Occupational Survey	- Occupationally exposed individuals are directly exposed on a frequent basis - Choice of worker populations is available - Previously carried out in LAC region - Can compare to a control group - Minimizes confounding from other lead sources	- Requires cooperation of individuals and willingness of employers to participate - Workers may potentially be exposed to other sources of lead - May require new interagency agreements - Confidentiality of results would have to be addressed to avoid discrimination against participants
Child Survey	- Previously carried out in LAC region with good participation from parents and school authorities - Can identify children with potentially high lead levels and assist with efforts to reduce elevated levels - Sampling selected schools in an urban environment is more efficient and provides better risk factor data - School environment can be used for information dissemination on health effects and prevention measures - Important population for targeting public policymaking	- Requires cooperation of school and government authorities - Requires parental authorization and education about the effects of lead on health and potential counseling follow-up - May be difficult to obtain blood samples from young children - Children surveyed may potentially be exposed to other sources of lead
Umbilical Cord Blood Survey	- Women easily accessible in hospitals and willing to consent to sample taking - The system can be run by hospital personnel - Processing of specimens in a timely fashion will permit opportunity for counseling - Non-invasive procedure facilitates data collection - Information on sources of exposure and prevention measures could be provided - Survey was previously conducted in LAC region	- Concerns about mobilization of lead from bone during pregnancy (confounding; masking effects) - Cord blood may not necessarily reflect current blood exposure - Survey administration requires additional expenses and time commitment from hospital staff - Population is representative only of females giving birth in hospitals and clinics - It may be difficult to establish direct relationship of lead levels with exposure levels - Lifestyle changes during the last month of pregnancy may decrease environmental exposure

Environmental Monitoring

	Advantages	Disadvantages
Survey of Leaded Gasoline Use	- Data collectible through government ministries and gasoline vendors - Inexpensive to do - Can be enhanced with addition of country-specific data on lead particulates in air	- Proxy or indirect measurement of lead in environment - Not informative about impact on health
Ambient Air Sampling	- Direct measurement of lead particulates - Can use high or low-volume air samplers	- May be difficult to collect data near sentinel populations or high traffic areas - Requires more infrastructure and resources

A 1991 study in Quito, Ecuador, (Bossano and Oviedo 1996; Oviedo et al. 1996) found that a cohort of female street vendors in their fertile years (N = 76, mean age 15.6 years, mean daily exposure time at work 9.7 hours), who were highly exposed to the combustion products of leaded gasoline, among other airborne contaminants, had a 70% higher mean blood lead level than a comparable group of pregnant housewives (N = 83; working in the home) from three different parts of the capital city (i.e., a cross-section of housewives). The respective blood lead levels were 30.3 μg/dL vs. 18.4 μg/dL in the two samples. This study suggests that such highly exposed worker populations are useful sentinels for leaded gasoline exposure.

There are potential challenges associated with targeting workers occupationally exposed to leaded gasoline. For example, the effort requires obtaining cooperation from employers as well as employees (this is a similar issue to sampling schoolchildren or women in hospital for birth). A survey or sampling of occupational lead exposure could result in workers requesting hazard pay or employers being concerned about inspections from government agencies and liability. Futhermore, many of these groups are not formally employed and have high job mobility making long term follow-up difficult.

Option: Periodic survey of children

This approach monitors children aged six months to six years attending day care or school. Previous blood lead level studies of school-age children have been successfully carried out in the LAC region with good participation from parents and schools, e.g., in Mexico by Olaiz et al. (1996a) and in Ecuador by Bossano and Oviedo (1996) and Oviedo et al. (1996). Information collected on school-age children monitors them further along the continuum of their development in contrast to younger children. The collection of blood lead samples and risk factor data via questionnaires is more efficient when done at several selected schools than at clinics dispersed throughout the city where children may be taken sporadically for well-care visits or immunizations.

The disadvantages of this approach are related to administrative and medical concerns. Sampling school-age children at school requires cooperation from school systems, principals, and state authorities. Parental authorization must also be obtained, which necessitates careful education about the rationale for the monitoring effort, awareness of the potential health effects of children s exposure to lead, and, if warranted, potential follow-up actions for children with high blood lead levels. It also may be more difficult to obtain blood specimens from younger children (1-3 years); however, phlebotomists appropriately trained in the collection of specimens from younger children can minimize the duration of discomfort (Schlenker et al. 1994).

Option: Periodic survey of umbilical cord blood lead levels from women at time of delivery

This approach relies on the collection of monitoring information from a sample of women delivering babies at selected city hospitals. From a biological perspective, umbilical cord blood lead represents exposure to lead in a special cohort of the adult population (pregnant women). (Silbergeld 1991, 1996.)
Women who go to a hospital at the time of their delivery can be accessible for blood lead monitoring, as has been shown in studies in Mexico City (Hernández-Avila et al. 1996), but investigators must be aware of confounding factors such as the effects of socioeconomic status on blood lead level (Farias et al. 1996).

A hospital-based monitoring system is run by professional hospital personnel, for whom training in specimen collection techniques is made easier by virtue of their education and professional relationship to women at the time of delivery. Appropriately selected hospital staff can also serve the monitoring effort by disseminating information on the health effects of lead to mothers. If blood lead levels are processed regularly, results can be made available in a timely fashion and counseling can be provided for the mothers.

The use of umbilical cord lead as an indicator of women s exposure to lead in gasoline is complicated by concerns about mobilization of lead from bone during pregnancy. The issue has been raised by some researchers that cord blood, at the time of delivery, is representative of long-term storage of lead in bone released back into tissues and blood; thus cord blood lead may not necessarily reflect current lead exposure (Silbergeld 1991, 1996). Researchers are currently debating the percentage of the contribution of mobilized (stored) lead to a woman s cord blood lead level *at the time of delivery* and confounding factors associated with mobilization of stored lead (e.g., dietary calcium, reproductive history, coffee consumption, and use of indigenous lead-glazed pottery) (Rothenberg et al. 1994; Gulson et al. 1995; Hernández-Avila et al. 1996). Reports of the percentage of the contribution of stored lead to cord blood lead vary (Hernández-Avila et al. 1996; Rothenberg et al. 1994; Silbergeld 1991) and are important for understanding the chronic nature of long-term lead exposure and accumulated body burdens of lead. However, studies of cord blood lead level measurements conducted in the United States, Australia, and Mexico have shown declining trends in cord blood lead levels consistent with declines in blood lead levels measured in the general population (McMichael et al. 1986, 1994; Hu et al. 1996a; Hernández-Avila et al. 1997; Pirkle et al. 1994). This international experience bodes well for detecting similar declines in cord blood levels of women throughout the LAC region. Although lead is mobilized from bone to maternal blood and consequently to umbilical cord blood, most studies using umbilical cord blood lead levels as an outcome measure have documented important declines in this biomarker in response to reductions in the lead content of gasoline (see Rabinowitz and Needleman 1983).

3.3 Environmental Monitoring

The primary lead exposure route from gasoline is via airborne particulates which are either inhaled, deposited on foods and ingested (e.g., on leafy vegetables or fresh fruits that are eaten unwashed), or ingested as dust on the fingers of toddlers and young children. Urban air monitoring information is available for a few LAC countries, which sometimes includes the lead fraction of particulates. For example, as a part of the WHO GEMS-AIR program, Venezuela collected data on lead particulate concentrations in ambient air from four long-term sampling stations in Caracas and in two other cities in 1992-1993 (Rondon 1996). Data collection could be done on a periodic basis during the course of the multi-year lead monitoring program. Data on air lead concentrations would provide valuable supporting evidence for the expected relationship between reduced lead in gasoline and reduced lead levels in the highly exposed populations.

Option: Ambient air sampling

The specific methods recommended for ambient air sampling for lead particulates are found in Section 7.1; they include both high-volume and low-volume samplers. Generally, environmental sampling of media such as ambient air should be conducted in environments with a high probability of substantial lead exposure (Howson et al., 1996). With respect to leaded gasoline, this refers to high traffic areas where workers are occupationally exposed or where residences and schools are located. If these locations are not practical, standard ambient air monitoring points (e.g., use of existing permanent air monitoring stations) would be acceptable. A recent survey conducted by the Pan American Health Organization was summarized in Lacasaña et al. 1996. The purpose of the survey was to collect information on the magnitude of lead pollution in the Caribbean. Information was collected on production, export, and import of lead (tons/year), sources of airborne lead emissions, information on studies determining blood lead levels, and rules and guidelines for control of lead pollution. Several findings of the survey are noteworthy. First, the overall response rate was 57% (16/28 countries responded); in Latin America the response rate was 72% (13/18), while in the Caribbean 30% of the countries responded. Second, lead content in gasoline varies from country to country (e.g., 1.31 g/L in Suriname to 0.05 g/L in Mexico). Third, only 36% of the countries in the LAC region have introduced unleaded gasoline into the market.

Respondents to the survey indicated that air lead levels have not been monitored on a continuous basis in most countries of the region with the exception of Brazil and Mexico. In 1996 the Association of Latin American Oil Companies (ARPEL) undertook a survey to characterize air pollution in LAC countries. The focus of the survey was to collect information on lead aerosol from combustion of leaded gasoline, respirable particulate matter from diesel engines and motorcycles, carbon monoxide in gasoline exhaust, and information on several other air pollutants. Information made available on the measurement of lead in soil, air, and blood was presented at the September 1996 meeting of the National Focal Points in Santiago, Chile. A summary of available country-specific information is provided in Table 5.

Option: Survey of leaded gasoline use

If the concentrations of lead in gasoline are known and the volumes of leaded gasoline sold in a city are known, these data can be used to make a rough estimate of the changes in the amount of lead released into the environment (ambient air) over time in that city. Changes in the amount of lead added to gasoline over a given period of time are often generated by the Ministry of Energy and/or the producers and wholesale vendors of gasoline in a country. These data can be used by the Ministry of Energy, Environment, or Health to estimate changes in lead exposure.

Table 5
Country-Specific Measurements of Lead in Soil, Air and Blood

	Lead Measurement in Soil in Urban Areas		Lead Measurement in Air in Urban Areas		Lead Measurement in Blood	
Country	**Yes/No**	**Values**	**Yes/No**	**Values**	**Yes/No**	**Values**
Anguilla	No		No		No	
Argentina	No		Yes	Conducted by Greenpeace (No data provided)	Yes	Conducted by Greenpeace (No data provided)
Bahamas						
Barbados	No		Yes	No yet completed, requires more air monitoring equipment	No	
Belize						
Bermuda	No		Yes	Impact of leaded to unleaded gasoline conversion on Bermuda		
Bolivia	No		No		Yes	Study of YPFB refinery worders over the last five years. 9.6% of workers analyzed had blood lead levels of 30 μg/dL or higher.
Brazil	N/R		N/R		N/R	
Chile	No		No		No	
Colombia	No		No		No	
Costa Rica	No		Yes	In some high density areas lead in air has been measured at 0.63 $\mu g/m^3$	Yes	Study of average population showed 17.09 μg/dL on ave. For workers in a battery plant the average was 66 μg/dL. 57% of children had levels above 10 μg/dL.
Cuba						
Dominica						
Dominican Republic	No		No		No	
Ecuador						
El Salvador	N/R		N/R		N/R	
Grand Cayman						
Grenada						
Guadeloupe						
Guatemala					No	
Haiti	No		Partial	A field study has been set up but due to a lack of money and manpower, it has not been executed.	No	
Honduras	No		Yes	Very high lead in air levels were found in metropolitan areas.	Yes	In 1994-1995, school children were checked and 67% were below 3.2 μg/dL, 19% had levels as high as 4.9 μg/dL and less than 1% were as high as 5.3 μg/dL.
Jamaica	Yes	Study currently underway	Yes	Study currently underway.	Yes	Study currently underway.
Martinique, FWI						
Mexico	Yes	Published in Enviro. Sci. Tech. Vol. 25, 1702 (1992)	Yes	Mexican bibliography about lead and health.	Yes	Report put out by World Health Organization.
Netherlands Antilles *	No		No		No	
Nicaragua	N/R		N/R		N/R	
Panama						
Paraguay	No		No		Yes	OCTEL conducts blood test on refinery personnel.
Peru	No		Yes	Study currently being developed.	No	
St. Lucia	No		No		No	
St. Kitts - Nevis						
Suriname	No		No		No	
Trinidad & Tobago	Yes	High level of lead found in urban roadside dust	Yes	Preliminary study confirmed emission of organic lead in atmosphere was from vehicle emissions.	Yes	High lead levels in blood for occupationally exposed persons and low levels for average rural populations. Average urban lead in blood levels were higher than average suburban and rural levels.
Turks & Caicos						

Uruguay	No		No		No	
Venezuela	N/R		Yes	Lead in air study done in 8 major cities with high leaded gasoline consumption.	Yes	Study determined that in cities which are in compliance with lead in air reg s, some individuals have a slight excess of lead in blood related to health standards of 15 μg/dL.

In a recent survey of LAC countries conducted by ALCONSULT International Ltd. (1996), data from 11 of 21 LAC countries were reported on lead in air at the time lead was added to gasoline and after lead was removed. Collection of additional country-specific air lead data would enhance this monitoring option by including baseline and prospective data on the impact of the phase-out of lead in gasoline.

3.4 Regional Resources for Assessing Lead Exposure

Several institutions and laboratories in the LAC region are available to assist country ministries with either field sampling or data analyses for environmental and biological lead specimens. The Pan American Health Organization (PAHO), based in Washington, D.C., is the primary international agency in the LAC region to address health issues posed by lead in the ambient environment and blood lead concentrations in humans. Several other institutions that can help in various aspects of lead monitoring and analysis are listed in Table 6.

For a country with no available blood lead analytical laboratory, environmental sampling laboratory, or epidemiological capacity, several regional and national institutions can assist with monitoring efforts. Readers are encouraged to contact those organizations.

Numerous laboratories in the LAC region are capable of blood lead analysis. To ensure standardized blood specimen analyses and to build upon currently existing laboratory capacity in the region, analysis should be conducted at a laboratory currently involved in the external QA/QC (proficiency testing) program of the PAHO/FIOCRUZ network (see Table 6 for details). A list of laboratories capable of blood lead analysis in that network is found in Appendix B.

Laboratories in the LAC region can also participate in various external QA/QC (proficiency testing) in North America (e.g., the CDC PT and Blood Lead Laboratory Reference System [BLLRS] programs) at little to no cost (see Table 5 for details). A list of LAC and North American laboratories currently involved in the U.S. CDC PT program for blood lead is provided in Appendix C. The blood lead laboratory analytical methods used by the U.S. CDC are found in CDC (1995).

Countries using the ambient air sampling option are encouraged to register and participate in the Environmental Lead Proficiency Analytical Testing (ELPAT) and Proficiency Analytical Testing (PAT) programs offered jointly by the CDC/NIOSH/ American Industrial Hygiene Association, or an equivalent program. There is little or no cost to participate in the PAT and ELPAT programs; see Table 6 for details.

3.5 Issues for Consideration

An important aspect in carrying out these monitoring activities is that the options be implemented in the context of existing programs and with current facilities in the LAC region. Monitoring should be incorporated into an existing health or environmental institution s activities or within the context of a university-based research group. The institutional locus of monitoring should be flexible, accounting for differing capabilities from country to country.

The intent behind the development of these monitoring options is to collect information as simply as possible in order to examine the impact of phasing out lead in gasoline in the LAC region, those

undertaking blood lead monitoring programs need to be prepared for the discovery of important sources of lead exposure other than leaded gasoline. As demonstrated by the case study in Peru, blood lead monitoring programs often reveal other sources of lead exposure. If these other sources of exposure are significant, from a public health point of view, follow up with study participants will be required and, potentially, interventions to reduce these other sources of exposure will be needed.

Table 6
Regional Resources Available for Environmental and Blood Lead Monitoring

Institute	Services Available	Person to Contact	Point of Contact
CESTEH/ENSP/ FIOCRUZ, FIOCRUZ Laboratory, Fundacão Oswaldo Cruz, Escola Nacional de Saúde Pública, Ministerio da Saúde, Rio de Janeiro, Brasil	Assistance with QA/QC for blood lead analysis, at FIOCRUZ (and also available in other member laboratories in this PAHO network) guidelines manuals round robin QA exercise intercalibration	PAHO/CESTEH Network Coordinator: Dr. Josino C. Moreira	Address: Rua Leopoldo Bulhões, 1480 Manguinhos Cx. Postal 926 Cep 21.04, Rio de Janiero, RJ, Brasil Telephone: (55 21) 290-0484 or (55 21) 598-3789, ramal 2198 Fax: (55 21) 280-8194 or (55 21) 270-3219 Internet: moreiraj@manguinhos.ensp.fiocruz.br
Centro de Investigaciones en Salud Poblacionel (CISP), Instituto Nacional de Salud Publica, Cuernavaca, Morelos, Mexico	Assistance in epidemiological data analysis	Dr. Mauricio Hernández-Avila, Director of CISP	Av. Universidad 655, Col. Sta. Maria Ahuacatitlan, 62508 Cuernavaca, Morelos, Mexico Telephone: (73) 17 53 91 Fax: (73) 11 11 48 Internet: mhernan@insp3.insp.mx
Centro de Investigaciones BRIMEX-II	Assistance in biological & environmental monitoring	Dr. Eduardo Palazuelos	The American British Cowdray Medical Center Sur No 166 Mexico DF, 01120 Telephone: 525-230-8268 Fax: 525-230-8269
BIREME/PAHO: Latin American and Caribbean Center on Health Sciences Information, São Paulo, Brasil	PAHO Center for Bibliographic Information and PAHO databse	Dr. Abel Laerte Packer, Systems and Data Processing	Rua Botucatu, 862, Vila Clementino CEP 04023-901, São Paulo SP, Brasil Telephone: (55 11) 576-9800 Fax: (55 11) 571-1919 or 575-8868 Internet:abel@bireme.br
CEPIS/PAHO: Centro Panamericano de Ingenieria Sanitaria y Ciencias del Ambiente, Lima, Peru, Division of Health and Environment, PAHO	Assistance with environmental lead sampling; environmental lead laboratory analysis	Ing. Sergio A. Caporali, Director of CEPIS	Los Pinos 259, Urb. Camacho, Lima 12, Peru; Casilla Postal 4337, Lima 100, Peru Telephone: (51 14) 371077 Fax: (51 14) 378289 Internet: scaporal@cepis.org.pe
GEMS/AIR Program	Provides country-specific and regional	Dr. Dietrich Schwela	Urban Environmental Health, WHO, 20 Avenue Appia, CH-1211

Institute	Services Available	Person to Contact	Point of Contact
	data on air particulates (including lead, where measured); also assistance in development of a GEMS/AIR monitoring program in a country		Geneva 27, Switzerland Telephone: (41 22) 791-4261 Fax: (41 22) 791-4127 Internet: schwela@who.ch
U.S. CDC/NIOSH/ American Industrial Hygiene Association	PAT and ELPAT Programs: Provide Proficiency Analytical Testing for *environmental* lead at no cost.	Fred Grunder, PAT Coordinator (air particulates on filters) Carl Bell, ELPAT Coordinator (other environmental lead media)	AIHA, 2700 Prosperity Avenue, Fairfax, Virginia 22031, USA Telephone: (703) 849-8888 Fax: (703) 207-3561 Internet: cbell@aiha.org
U.S. CDC, Environmental Health Division, Environmental Health Laboratory, Atlanta, Georgia	Provides Blood Lead Laboratory Reference System (BLRRS) and Proficiency Testing (PT) programs, laboratory technical assistance & blood lead reference materials, without charge.	Dr. Daniel C. Pascal or Dr. Robert L. Jones, Supervisory Research Chemists	U.S. CDC, Environmental Health Division, Environmental Health Laboratory Attention: BLLRS and PT Coordinators, Mail Stop F-18, 4770 Buford Highway, Atlanta, Georgia 30341-3724 Telephone: (770) 488-7985 or (770) 488-7991 Fax: (770) 488-4097 Internet: rlj0@cdc.gov jfm7@cehehl1.em.cdc. gov
U.S. CDC, Field Epidemiology Training Programs (FETP), Atlanta, Georgia	Provides technical assistance in epidemiological analysis of data. (Local FETP offices exist in several countries in LAC region.)	Director, Division of Field Epidemiology, International Branch	U.S. CDC, Attention: Director, Division of Field Epidemiology, International Branch 1600 Clifton Rd, NE, MS-C-08, Room 5104, Atlanta, Georgia 30333 Telephone: (770) 639-2231 Fax: (404) 639-2230 E-mail: mhw1@cdc.gov
Field Epidemiology Training Programs in the LAC Region			
COLOMBIA Servicio en de Epidemiologia Aplicada (Applied Epidemiology Service)		Fernando de la Hoz, MD, Director	Instituto Nacional de Salud, Avenida Eldorado y Carrera 50, Santafe de Bogotá, Colombia Telephone: 57-1-2220577 Fax: 57-1-2223294, 57-1-2220194, 57-1-2223055, 57-1-3151890 E-mail: fdelahoz@openway.com.co
CAREC		Director, Caribbean Epi Center, Trinidad	1618 Jamaica Blvd., Port of Spain, Trinidad, West Indies

Institute	Services Available	Person to Contact	Point of Contact
			Telephone: 809-622-4261 Fax: 809-622-2792 E-mail: trinidadlb@wow.net
BOLIVIA		Antonio Gomez, Director Lucio Lantaron, Coordinator, Community and Child Health/DDM	Calle Giotia, Casilia No 14384, La Paz, Bolivia Telephone: 591-2-37-89-39, 591-2-37-63-31 Fax: 591-2-39-15-03 E-mail: si@gsecch.bo
MEXICO Epidemiologia Aplicada (PREA)		Dr. Rodolfo Mendez Vargas, Director of Epidemiologic Surveillance of Non-communicable Diseases Dra. Evangelina (Eva) Gonzales, Director Ejecutiva Dra. Elizabeth Alvarado, Coordinator, PREa Paplo Kuri, Director, DGE	Dirección General de Epidemiologia FCO De P. Miranda 177, 3er Piso, Col. Lomas de Plateros, Delegación Alvaro Obregon DF 01480 Mexico Telephone: 525-651-6970/6288 (Mendez) 525-593-3661 (Gonzales) 525-588-7149 (Avilla) 525-593-0824 (Kuri) Fax: 525-651-8700 (Mendez) 525-593-3661 (Gonzales) E-mail: jpvilla@epi.org.mx Ealvar@epi.org.mx
PERU Programa de Especialización en Epidemiologia de Campo (PREC)		Sr. Dr. Mario Chuy Chiu, MSP Augusto Lopez Rodrigues, MD, PhD	Oficina General de Epidemiologia, Minsterio de Salud, Jr Camilo Carrilo 402, Jesus Maria, Lima, 11-Peru Augusto Lopez Rodriguez: Eduardo Bello 375, Urb Santa Catalina, Lima 13-Peru Telephone: 51-1-433-5859, 51-1-433-5428, 51-1-462-4377 (home, Dr. Lopez) Fax: 51-1-4336140, 51-14-330081 E-mail: auglopez@amauta.rcp.net.pe

PART B: STUDY DESIGN AND PROTOCOLS

4 STUDY DESIGN FOR SURVEY OF OCCUPATIONALLY EXPOSED WORKERS

4.1 Recruitment of the Study Population

Population groups that are highly exposed to lead from gasoline should experience substantial declines in blood lead levels when lead is reduced or removed from gasoline. Using this rationale, groups receiving high occupational exposure are appropriate for monitoring the impact of the phase-out of lead in gasoline. Because they have high exposure to leaded gasoline, these groups are also likely to experience the largest changes, therefore maximizing the statistical power of the evaluation. Evidence can be strengthened by comparing changes observed in these groups to those in nonexposed individuals (control group) from a similar socioeconomic level and with a comparable age and gender composition.

The first step is to identify groups that are occupationally exposed to automobile emissions or gasoline products (for example, traffic police, bus or taxi drivers, street vendors, shoe shiners, or gasoline station pump attendants). Initial interviews with employers or union leaders may help to assess the feasibility of the study and will facilitate field work and study participation. If possible, subjects should be selected at random from payroll, membership, or other lists. Because subjects will be followed for 5 to 10 years, it is important to convey this information up front to ensure that the study groups contain highly motivated individuals who are more likely to participate fully in the study. Similarly, the study population should include permanent rather than temporary employees as the latter are more likely to change jobs, making them ineligible to continue the study. Also, follow-up is more difficult with temporary employees, which may compromise the validity of the study.

Selecting the control group will be easier once the exposed group is selected and sampled. For example, if the occupational group includes traffic police aged 20 to 35, the nonexposed group should also include men and women from a similar socioeconomic level, aged 20 to 35 years who are not traffic police. In addition, the control group should not have been exposed to significant ambient atmospheric pollution or to lead from other occupational sources (e.g., radiator repair shops, battery smelting, and print shops). The age-gender distribution of groups can be made comparable by using frequency or pair matching when the control group is recruited.

4.2 Sample Size and Follow-Up

The primary hypothesis to be tested is that individual blood lead levels will decrease significantly over time during the phase-out of lead from gasoline. However, because policymakers and public health officials require feedback at shorter time intervals, we have proposed that sample sizes need to be adequate to detect estimated annual differences in blood lead levels. To estimate the required sample size, we used data from 179 subjects who participated in a blood lead survey in Madras, India (Potula and Hu 1996). In this study, 88 traffic police had a mean (SD) blood lead level of 11.2 μg/g

(8.8 μg/g). The estimated sample sizes to detect subsequent declines in blood lead levels ranged from 70 subjects to detect a decline of 3.0 μg/dL to 860 to detect a decline of 1.0 μg/dL (Table 7). The estimated difference to be detected between the first and second evaluations will depend on the magnitude of the decrease of the lead content in gasoline. For example, in England, significant differences were detected among police between 1985 and 1986 after the lead content of gasoline decreased from 0.4 to 0.15 g/L (Quinn and Delves 1989). The loss of participants due to individuals migrating or refusing to participate over time is difficult to foresee, but it is always safe to increase sample sizes by 20% or more, if budgetary conditions allow, to prevent bias or loss of statistical power originating from this problem. The required sample size will depend on the amount of variation in blood lead levels in the study population, local conditions and other characteristics of the population to be studied. Small pilot studies should be conducted to obtain information needed to estimate appropriate sample size requirements and to test field procedures.

Once the programmatic actions that are needed to phase-out lead from gasoline are begun, selected subjects should be reexamined annually as recommended by Quinn and Delves (1987) for the UK Blood Lead Monitoring Program. In some LAC countries serial blood lead concentrations have been found to vary significantly from season to season (Farias et al. 1997). To avoid any seasonal distortion of results, it is important to conduct evaluations as close as possible to the same time of year as when the baseline evaluation took place.

Table 7
Estimated Sample Sizes Needed to Detect Declines in Blood Lead Levels

Expected Decline in Blood Lead Levels (μg/dL)	Correlation between Measurements	SD of the Difference	Estimated Sample Size
1.0	0.30	10.4	860
1.0	0.50	8.8	610
1.5	0.30	10.4	380
1.5	0.50	8.8	270
2.0	0.30	10.4	220
2.0	0.50	8.8	160
3.0	0.30	10.4	100
3.0	0.50	8.8	70

Calculations assume a mean (SD) blood lead level at baseline of 11.2 μg/dL (8.8) with a statistical power of 80% and a 95% confidence level.

4.3 Questionnaire Information

Brief questionnaires should be used to assess the following:

•Basic demographics and socioeconomic characteristics of the study population
•Information regarding exposure to other sources of lead (for example, consumption of canned foods, cigarette smoking, wine consumption, use of lead-glazed ceramics, home remedies that may be contaminated with lead, hobbies that may involve use of lead, area of residency, exposure to road traffic)
•Information to assess exposure at the workplace (for example, number of working hours, job category, job changes in recent months, hygiene practices at work, cleaning of work clothes, eating and smoking in the workplace)
•Information to follow up subjects and to track and locate those lost to follow-up.

In addition, detailed information including home address and telephone numbers at work and home (if available) should be obtained. Information regarding friends or family also should be collected to help locate subjects in case of loss to follow-up.

Because information may vary over time, results must take into account changes in any variable associated with lead exposure. For example, if hygiene practices improve at the workplace during the study period, it may be difficult to distinguish the effects of reducing gasoline lead content from those obtained by improving hygiene practices. However, if information regarding changes in other sources of lead is available, this may be used to adjust results and obtain better estimates regarding the effect of gasoline lead content reductions. Appendix D provides examples of the types of questions to include for occupationally exposed workers.

4.4 Data Analysis

The questionnaire information and blood lead results for each worker should be entered into a database to generate descriptive statistics. Database entry should include range and value checking in order to control for digitization errors. Each subject should have a unique identification number. This number should be used to add new information collected for each subject during follow-up evaluations. For all analyses, lead levels should be transformed logarithmically to reduce asymmetry. The conversion of mean logs back to raw units provides a geometric mean level, which will be the primary summary statistic.

Data analysis of baseline information for both the study group and the control group should evaluate the association between independent risk factors and blood lead levels (e.g., cigarette smoking, diet, hobbies, location of worker s home in relation to traffic or industrial sources of lead, hygiene habits at work, number of hours worked). Univariate statistics should be calculated and evaluated against blood lead level measurements. Tests using t-test or analysis of variance should be performed. In addition, multivariate models could be constructed to include all potential predictors. For example, risk factors identified in the univariate analysis as important could be entered in a stepwise regression analysis to to analyze simultaneously the effect of different risk factors, and to determine those that contribute most significantly to workers blood lead levels. The odds ratios or relative risks of having a high blood lead level (higher than 25 μg/dL) could also be estimated according to different variables. Multivariate modeling could be conducted by using logistic regression models.

To compare the first and second blood lead measurements, various approaches could be used. Performing a paired t-test between the first and second measurements is one example. While relatively simple, however, this test will ignore important predictors of blood lead levels that may have changed over time and that could confound the observed differences in blood lead levels. It is recommended that multivariate adjustment be done using statistical methods for longitudinal data.

4.5 Blood Sampling and Laboratory Analysis

The recommended procedure for blood collection in these groups is venipuncture rather than finger stick. Given that occupationally exposed populations have a high level of contact with environmental lead, skin surface may be highly contaminated with lead particles that are difficult to eliminate by simple handwashing. Because finger stick procedures are highly sensitive to contamination by skin lead particles, that technique is not recommended for this group. The difficulty of controlling lead contamination of the skin prick site can lead to a large number of invalid samples.

Either graphite furnace atomic absorption spectophotometry (GFAAS) or anodic stripping voltametry (ASV) should be used to determine blood lead levels, whenever these measurement techniques are available and working with the appropriate quality controls. However, if these procedures are not readily accessible, the new ASV-based portable technology (LeadCare™ portable instruments) can be used. These battery-powered instruments, the size of a hand-held calculator, are simple to use, require neither manual calibration nor refrigeration, can measure blood samples obtained either by venipuncture or finger stick, and give blood lead results within minutes, providing a good opportunity to conduct on-site counseling.

Regardless of the method used to determine blood lead levels, maintenance of accurate blood lead measurements over the study period is key to obtaining valid results. To avoid or minimize laboratory error in lead measurements over time, it is important to develop and maintain a program of external quality assurance/quality control (proficiency testing). In such a program, external reference materials are inserted into the sample stream as true blind quality control samples. Several institutions offer this type of standardization program (see Table 6); the authors of this report recommend that laboratories join the program offered by the Environmental Health Division of the U.S. Centers for Disease Control and Prevention (CDC). Under that program, bovine blood samples are supplied free of charge by the Blood Lead Laboratory Reference System (BLLRS) to laboratories doing blood lead analysis. These samples help laboratories standardize their blood lead measurements so that they can monitor and maintain consistent and accurate measurements over time. Difficulties in implementing this program often include country-specific regulations regarding the importation of bovine-based materials. The authors recommend that all regulations be verified and permits obtained before the study starts.

4.6 Counseling for High Blood Lead Levels

Study participants should be counseled regarding their blood lead levels and educated about how to keep them low. It is important to know that occupational lead standards vary considerable from country to country. Currently, the U.S. Occupational Safety and Health Administration (OSHA) protects workers by removing them from the workplace when blood lead levels exceed 50 μg/dL. In addition, the removed worker cannot be returned to a job with high levels of exposure until their

blood lead level is $\leq$ 40 μg/dL. For this study, it is recommended that all workers whose blood lead levels are above 25 μg/dL receive special counseling to provide information about how to reduce blood lead levels. Workers with levels above 40 μg/dL should be retested for confirmation and, if positive, should be investigated for additional sources of lead exposure and referred for medical evaluation. Subjects who receive special counseling or treatment should be excluded or flagged in subsequent statistical analysis.

4.7 Reporting Results and Information Dissemination

Following the annual analysis of the data, a report should be prepared and sent to all ministries participating in the monitoring program. The report should include mean blood lead levels as well as the percentage of participants who are above certain levels deemed critical to public health. Action levels for occupationally exposed individuals could be set at 25 μg/dL (additional counseling) and 40 μg/dL (consider changes in work place procedures to reduce exposure or removal from workplace. Creating a table that compares observed blood lead levels with those reported in other countries may be of interest and will help readers to better understand the results. If the results uncover any additional risk factors for high blood lead levels, these should be reported as well. Because this report will probably reach a wide multidisciplinary audience, it is important not to use complex medical terminology. Preparing press releases on the results should also be considered.

5 STUDY DESIGN FOR SURVEY OF SCHOOL-AGE CHILDREN

5.1 Recruitment of the Study Population

One of the primary goals of reducing lead in gasoline is to prevent children's exposure to lead. Monitoring blood lead changes in cross-sectional samples of young children will provide direct information regarding health outcomes in this target population. In addition, because childhood lead poisoning may result from various sources, studying this group could provide information about other important risk factors for elevated blood lead. This may help in identifying sources of lead in addition to gasoline that could be targeted in a more comprehensive program to control lead exposure.

Recruitment of study participants should be the result of a multistage selection procedure. For example, in a first step, three to five districts with higher exposure to vehicular traffic could be selected at random. A list of schools from the selected districts should be obtained; school location should be plotted on a map to identify those situated in areas of high traffic, along highways, and in center-city neighborhoods. From this list, 20 schools should be selected at random.

Once schools are selected, proper contacts should be initiated to obtain authorization for the study to be conducted. Contacts should include authorities from the governmental agency responsible for school coordination and local school authorities. Once school participation has been granted, meetings to explain details of the study should be scheduled with teachers and parents.

The authors recommend the study of school-age children because that population is accessible and easily identified through the school system. Furthermore, the fact that children are grouped in schools and that schools can be selected according to exposure to environmental lead (i.e., at sites within high traffic districts) makes the study of this population cost effective. The studied samples are also comparable over time. Children attending the same school will be comparable in terms of socioeconomic characteristics and other factors that may be related to lead exposure.

Younger children (6 months to 2 years of age) who are at a higher risk of exposure and of suffering the neurotoxic effects of lead may also be studied. Selection procedures to study this age group can be based in random sampling or selection within health clinics or hospitals. See for example the case study in Peru (described in Section 2.5). The final choice of the study population will depend on local facilities as well as the available budget.

5.2 Sample Size and Follow-Up

The primary hypothesis to be tested is that mean blood lead levels of successive cross-sectional samples of children of similar age, gender, and socioeconomic background will decrease significantly over time as a result of the phase-out of lead from gasoline. However, because policymakers and public health officials may request feedback at shorter time intervals, the authors of this report have estimated sample sizes needed to detect estimated annual differences in blood lead levels. To estimate the required sample size, data from various studies have been used. One study was the U.S. National Health and Nutrition Examination Survey (Pirkle et al. 1994). Based on that study, a conservative prediction would be a reduction of about 1 μg/dL per year in the mean blood lead level. Other studies (Quinn and Delves 1987; Rothenberg et al. 1998) have documented larger declines: 1.5 μg/dL in the United Kingdom and 2.2 μg/dL in Mexico City, respectively. According to published studies, sample sizes need to detect differences in a range of 1 to 2 μg/dL were calculated. However, the expected value for the difference to be detected between the first and second cross-sectional samples will depend on how significantly lead in gasoline is decreased. The standard deviations (SD) of cross-sectional surveys in the literature reviewed vary widely. Sample sizes have been estimated for a low SD of 4.0 and a high SD of 8.0. Sample sizes range from 1,000 to 70 children per group depending on the different assumptions used in the sample size calculations (Table 8). The required sample size will depend on the amount of variation in blood lead levels in the study population, local conditions and other characteristics of the population to be studied. Small pilot studies should be conducted to obtain the information needed to estimate appropriate sample size requirements and to test field procedures.

Table 8
Estimated Sample Sizes Needed to Detect Differences in Blood Lead Levels between Two Populations

Expected Decline in Blood Lead Levels (μg/dL)	Estimated Standard Deviation of Blood Lead Levels	Estimated Sample Size per Group
1.0	8.0	1000
1.0	4.0	250
1.5	8.0	450
1.5	4.0	120
2.0	8.0	250
2.0	4.0	70

Calculations were made assuming varying SD, with a statistical power of 80% and a 95% confidence level.

Once the programmatic actions to phase-out lead from gasoline are begun, cross-sectional samples should be studied annually, as suggested by Quinn and Delves (1987) for the UK Blood Lead Monitoring Program. As mentioned, seasonal variations may confound results; therefore, it is important to conduct studies as close as possible to the same time of year when the first population was studied.

5.3 Questionnaire Information

Information relevant to the risk of lead exposure should be collected. The survey questionnaire should include age, gender, weight and height, and if possible some information regarding school performance of the child; residential location; industrial or commercial activities located near the child s residence that release lead into the air (e.g., gasoline stations, paint manufacturing industries, heavy metal smelters, battery manufacturers) and vehicular traffic in the street where his/her household is located; the child s diet and nutritional status; the use of lead-paint glazed pottery for food storage and cooking in the home; the parent s education, occupation, and hobbies; activities or behaviors of the child which may cause exposure to lead (e.g., chewing lead-paint pencils, playing in dirt). Information on the household use of lead-based paint may vary by country and region but should also be considered in assessing potential sources of lead exposure.

A standardized questionnaire should be used to gather this core set of demographic, environmental, and behavioral data. This information will be useful for checking high outliers in the blood lead data. Unusually high lead concentrations will likely be associated with other risk factors such as pottery use or secondary occupational exposure. These data could also be useful in multi-variate analyses of the determinants of elevated blood lead levels, especially with data pooled from several schools over several years. The collection and use of questionnaire data requires careful training of interviewers, validation of questionnaires, and other efforts to assure data quality. Additions to, but not deletions from, the core set of questions can be made to adapt the survey to specific risk factors that may vary from country to country. Appendix D provides examples of the types of questions to include for children.

5.4 Data Analysis

The questionnaire information and blood lead results for each participant should be entered into a database to generate descriptive statistics. Database entry should include range and value checking in order to control for digitization errors. Each subject should have a unique identification number. For all analyses, lead levels should be transformed logarithmically to reduce the asymetry of the distribution. The conversion of means logs back to raw units provides a geometric mean level, which will be the primary summary statistic.

Data analysis of baseline information should evaluate the association between independent risk factors and blood lead levels (e.g., children s behaviors that may increase the risk of lead exposure, such as time spent outdoors; the deliberate consumption of earth, soil, or clay; chewing or sucking of pencils, crayons, or toys; or placing hands in their mouths and handwashing practices). Univariate statistics should be calculated and evaluated against blood lead level measurements. Tests of significance should be performed using t-test or analysis of variance. In addition multivariate models can be constructed to include all potential predictors. For example, those identified in the univariate analysis as important can then be entered in a step-wise regression analysis to obtain the best model and analyze simultaneously the effect of different variables and to determine which ones contribute most significantly to children s blood lead levels. The odds ratios or relative risks of having a high blood lead level (higher than 10 ug/dL) could be estimated according to different variables. Multivariate models could be conducted by using logistic regression models.

The following points outline the data analysis to be performed over the course of the surveys of schoolchildren:

1. Inspect the data at the time of collection to detect outliers and potential problems with sample collection and analysis.
2. Conduct linear trend analyses, using analysis of variance (ANOVA), over the first, third, and fifth years (and over the whole 10 years, when these data are available). This analysis will specifically test whether or not there is a systematic trend in lead levels over the years studied. Access to personal (desktop) computers with standard statistical software should be adequate for data analysis. (Epi-Info is commonly available in the LAC region. Other options include SYSTAT or SAS.)
3. It may be useful to group the first three years and the last three years, then compare using ANOVA.

Statistical comparisons should be made by ANOVA; the primary independent variables are likely to be residential location, hygiene behavior, and other sources of lead exposure. Evaluation of the distribution of blood lead levels of the populations surveyed will provide important information relative to regulatory benchmarks established within countries in the LAC region and can be used to evaluate progress toward country-specific objectives for lead exposure.

5.5 Blood Sampling and Laboratory Analysis

A sample protocol for collection of blood specimens is provided in Appendix E. The recommended procedure for collection of blood specimens (finger stick) for children requires preparation of a clean room and facilities for hand washing. All samples should be collected in containers certified lead-free by manufacturer. Blood lead should be measured by anodic striping voltametry using portable devices at the testing sites. These instruments(LeadCare portable instruments) are the size of a hand calculator, are simple to use, and require neither manual calibration nor refrigeration and provide blood lead results within minutes, thus providing an opportunity to conduct on-site counseling. When the results indicate a high value, for example over 30 μg/dL, the test should be repeated after a second hand washing. Values which are reconfirmed as high should be confirmed once again with the sample obtained by venipuncture following procedure outlined in Appendix E.

Regardless of the method used to determine blood lead levels, maintenance of accurate blood lead measurements over the study period is key to obtaining valid results. To avoid or minimize laboratory error in lead measurements over time, it is important to develop and maintain a program of external quality assurance/quality control (proficiency testing). In such a program, external reference materials are inserted into the sample stream as true blind quality control samples. Several institutions offer this type of standardization program (see Table 6); the authors of this report recommend that laboratories join the program offered by the Environmental Health Division of the U.S. Centers for Disease Control and Prevention (CDC). Under that program, bovine blood samples are supplied free of charge by the Blood Lead Laboratory Reference System (BLLRS) to laboratories doing blood lead analysis. These samples help laboratories standardize their blood lead measurements so that they can monitor and maintain consistent and accurate measurements over time. Difficulties in implementing this program often include country-specific regulations regarding the importation of bovine-based materials. The authors recommend that all regulations be verified and permits obtained before the study starts.

5.6 Counseling for High Blood Lead Levels

Parents of study participants should receive counseling regarding their child s blood lead level as well as educational information about how to reduce lead exposure. Current recommendations by the American Academy of Pediatrics (Screening for Elevated Blood Lead Levels 1998) include the following actions: if the blood test result is >70 μg/dL, the test should be repeated immediately; within 48 hours if the result is between 45 and 69 μg/dL; within 1 week if the result is between 20 to 44 μg/dL; and within 1 month if the result is 10 to 19 μg/dL. These recommendations are cost-effective and work well in countries that have phased out lead from gasoline, because only a relatively low proportion of screened children are likely to require confirmation and because additional point sources may be identified in children with high lead levels.

However, for LAC countries where leaded gasoline is still in use, these test result criteria may not work efficiently; a large proportion of children are likely to have levels above the 10 μg/dL cut-off point, due solely to their exposure to lead derived from gasoline. Based on this, the following modifications are recommended: if the blood test result is >70 μg/dL, the test should be repeated immediately; within 48 hours if the result is between 45 and 69 μg/dL; within 1 week if the result is between 30 to 44 μg/dL; and within 1 month if the result is 20 to 29 μg/dL.

Treatment guidelines should be developed for children with high blood lead before the start of the project. It is outside of the scope of this document to provide a review of the clinical issues related to lead intoxication. However, several key publications that provide a detailed review and recomendations regarding the pharmacological treatment of lead intoxication are available: Committee on Drugs (1995); Sargent (1994); Liebelt and Shannon (1994); Glotzer (1994).

Medical treatment with some chelating agents is contraindicated if the intoxicated child will remain in contact with the original lead source or will return to a high lead environment. Several studies have documented that children who were chelated and then returned to high lead environments recover their original high blood lead levels within weeks, increasing the risk for acute lead toxicity. The current recommendation by the American Academy of Pediatrics is that children with blood lead levels higher than 45 μg/dL receive chelation therapy and be removed from the lead source. Whenever possible the source should be identified by conducting a detailed environmental investigation of cases with high blood lead levels (>30 μg/dL). Frequently children are exposed to lead by contact with contaminated dust or soil, due to their propensity to put into their mouths fingers, toys, and other objects. Interventions to promote improved hygiene and handwashing will be an important action to reduce lead exposure.

5.7 Reporting Results and Information Dissemination

Following the annual analysis of the data, a report should be prepared and sent to all ministries participating in the monitoring program. The report should include mean blood lead levels as well as the percentage of participants who are above certain levels that are of public health significance. For children and young infants these cut-off points could be set at 10 μg/dL and 20 μg/dL. (The 20 μg/dL level is used to flag those children requiring additional follow-up, while the 10 μg/dL value is used to flag those children who have levels over the limit of concern.) A table that presents observed blood lead levels along with those reported for other countries might help readers better understand the results. When survey results uncover any additional risk factors for high blood lead levels, these should also be reported. Because it is expected that the survey results will be of interest to a wide audience, it is important not to use complex medical terminology. Additional considerations should be given to the preparation of a press release for the general population.

6 STUDY DESIGN FOR SURVEY OF UMBILICAL CORD BLOOD

6.1 Recruitment of the Study Population

Lead is a well-recognized threat to the fetus. Fetal exposure may be evaluated by measuring blood lead levels in maternal or umbilical cord blood samples. In large urban settings deliveries take place in well-organized maternity wards, making hospitals a cost-effective setting to obtain umbilical cord samples. Furthermore, umbilical cord samples are easy to obtain and entail no discomfort to the mother or infant.

Selection of study participants should be based on a systematic sample of deliveries taking place during a specific time period. The hospitals selected for the study should ensure representation of different ethnic and socioeconomic backgrounds. For example, as a first step, three to five large maternity hospitals that provide medical care for normal pregnancies (i.e., those without complications) should be identified. Hospitals that provide care to well defined populations should be selected preferentially. The location of hospitals in the study should be plotted on a map to identify the geographic area covered.

6.2 Sample Size and Follow-Up

The primary hypothesis to be tested is that the mean blood lead level of successive cross-sectional samples of umbilical cord blood at time of delivery for women of similar age and socioeconomic background will decrease significantly over time as a result of the phase-out of lead from gasoline. However, because policymakers and public health officials may need feedback at shorter time intervals, sample sizes needed to detect estimated annual differences in blood lead levels have been calculated. To this end, the authors have used data from studies in Mexico City, Mexico, (Hernández-Avila et al. 1997) and Lima, Peru (see case study in Chapter 3). The reported means (SDs) in these studies were 6.64 (3.65) and 3.76 (2.52) for Mexico City and Lima, respectively. The authors based the sample size calculations on a conservative reduction in mean blood lead of about 1 μg/dL per year. However, the expected value for the difference to be detected between the first and second cross-sectional samples will depend on the magnitude of the decrease of the lead content of gasoline. Samples sizes have been estimated for a low SD of 2.0 and a high SD of 4.0. Samples sizes range from 20 to 250 newborns per group, depending on the different assumptions used in the sample size calculations (Table 9). The required sample size will depend on the amount of variation in cord blood levels in the study population, local conditions and other characteristics of the population to be studied. Small pilot studies should be conducted in order to obtain the information needed to estimate appropriate sample size requirements and to test field procedures.

Table 9
Estimated Sample Sizes Needed to Detect Differences in Umbilical Cord Blood Lead Levels between Two Populations

Expected Decline in Blood Lead Levels (μg/dL)	Estimated Standard Deviation of Blood Lead Levels	Estimated Sample Size per Group
1.0	4.0	250
1.0	2.0	140
1.5	4.0	120
1.5	2.0	30
2.0	4.0	70
2.0	2.0	20

Calculations were made assuming varying Standard Deviation, with a statistical power of 80% and a 95% confidence level.

Cross-sectional samples should be repeated on an annual basis once the programmatic actions to phase-out lead from gasoline are put into practice. As mentioned earlier, variations from season to season may confound results. Therefore, as far as possible, repeated studies should be conducted at the same time of the year.

6.3 Questionnaire Information

A brief risk-factor questionnaire concerning potential sources of exposure to lead should be administered to the women giving birth. The questionnaire can be developed in collaboration with local health care workers and should include a core set of questions regarding potential sources of lead exposure, demographic information, and information on occupational and environmental exposures, medical and reproductive history, and nutritional habits. Appendix D provides examples of the types of questions to inlcude for pregnant women.

6.4 Data Analysis

The questionnaire information and umbilical cord blood lead results should be entered into a database to generate descriptive statistics. Database entry should include range and value checking to control for digitization errors. Each subject should have a unique identification number and a variable indicating the year the survey was conducted.

Data analysis of baseline information should evaluate the association between independent risk factors and blood lead levels (e.g., the mother s cigarette smoking, diet, hobbies, home location in relation to traffic or industrial sources of lead, time living in the city). Univariate statistics should be calculated and evaluated against blood lead level measurements. Tests of significance should be performed using t-test or ANOVA.

In addition multivariate models could be constructed to include all potential predictors. For example, risk factors identified in the univariate analysis as important could then be entered in a stepwise regression analysis to analyze simultaneously the effect of different risk factors, and determine which of them contribute most significantly to umbilical cord blood lead levels. The odds ratios or relative risks could also be estimated according to different risk factors. Multivariate modeling could be conducted using logistic regression models.

For comparison of the first and second blood lead measurements, various approaches could be used. A simple one would be to perform a t-test between the first and second measurements. However, a t-test ignores other risk factors that may vary in the samples compared.

Given that the sample may have a broad geographical dispersion, additional analysis should be done regarding location of residence. If possible, the address where each participant has lived for the last two to three months should be identified on a map of the city. Geographical clustering of high umbilical cord lead levels may suggest the existence of point sources of lead exposure.

6.5 Blood Sampling and Laboratory Analysis

The recommended procedure for blood collection in these groups is puncture of the umbilical cord (see Appendix E for a complete protocol). All samples should be collected in containers certified by the manufacturer to be lead free. Either graphite furnace atomic absorption spectophotometry (GFAAS) or anodic stripping voltametry (ASV) should be used to determine blood lead levels, whenever these measurement techniques are available and working with the appropriate quality controls. However, if these procedures are not readily accessible the authors recommend the use of new ASV based portable technology (LeadCare™ portable instruments). These battery-powered instruments are the size of a hand calculator, simple to use, require neither manual calibration nor refrigeration, can process blood samples obtained either by venipuncture or by finger stick, and give blood lead results within minutes, providing the opportunity to conduct on-site counseling.

Regardless of the method used to determine blood lead levels, maintenance of accurate blood lead measurements over the study period is key to obtaining valid results. To avoid or minimize laboratory error in lead measurements over time, it is important to develop and maintain a program of external quality assurance/quality control (proficiency testing). In such a program, external reference materials are inserted into the sample stream as true blind quality control samples. Several institutions offer this type of standardization program (see Table 6); the authors of this report recommend that laboratories join the program offered by the Environmental Health Division of the U.S. Centers for Disease Control and Prevention (CDC). Under that program, bovine blood samples are supplied free of charge by the Blood Lead Laboratory Reference System (BLLRS) to laboratories doing blood lead analysis. These samples help laboratories standardize their blood lead measurements so that they can monitor and maintain consistent and accurate measurements over time. Difficulties in implementing this program often include country-specific regulations regarding the importation of bovine-based materials. The authors recommend that all regulations be verified and permits obtained before the study starts.

6.6 Counseling for High Blood Lead Levels

Study participants should receive counseling regarding their child s estimated blood lead levels as well as educational information about how to reduce lead exposure. Current recommendations from

the American Academy of Pediatrics (Screening for Elevated Blood Lead Levels 1998) include the following actions: if the blood test result is >70 μg/dL, the test should be repeated immediately; if the result is between 45 and 69 μg/dL, the child should be retested within 48 hours; the child should be retested within one week if the result is between 20 and 44 μg/dL and within one month if the result is between 10 and 19 μg/dL. In Latin America, where leaded gasoline is still in use, these criteria for retesting may not work efficiently, because it is expected that a large proportion of newborns will have levels above the 10 μg/dL cut-off point, due to placental transfer of maternal lead. Based on this expectation, the following modifications are recommended: if the blood test result is >70 μg/dL, the test should be repeated immediately (in both the mother and the newborn); if the result is between 45 and 69 μg/dL, the infant and his/her mother should be retested within 48 hours; if the result is between 30 and 44 μg/dL, the both (infant and mother) should be retested within one week; and retesting should occur within one month if the result is between 20 and 29 μg/dL.

For all newborns with levels above 30 μg/dL, further investigations should include a detailed environmental history and, if possible, a home visit to find out if there are additional point sources of lead exposure.

6.7 Reporting Results and Information Dissemination

Following the annual analysis of the data, a report should be prepared and sent to all ministries participating in the monitoring program. The report should include mean blood lead levels as well as the percentage of participants who are above certain levels considered to be of public health significance. For newborns, the cut-off point could be set at 10 μg/dL. Additionally the report should include the proportion of children who have values above 20 µg/dL. A table that compares blood lead levels found in the annual study with those reported by other countries may help readers understand the results. When survey results uncover any additional risk factors for high blood lead levels these should be reported. Because it is expected that this report will reach a wide multidisciplinary audience, the document should not use complex medical terminology. Additional consideration should be given to the preparation of press releases for the general population.

7 AIR MONITORING FOR LEAD

Airborne lead particulates in ambient air represent a potential hazard to children and adults in the LAC region. The size and chemical composition of lead particles emitted vary according to the emission source. Lead sulfates and sulfides originate from mines. Fugitive dust becomes airborne from open mounds of ore concentrate and smelters. Lead halides or lead double salts are originated from mobile sources (gasoline emissions). Both gasoline combustion and smelting processes emit small-size particles (less than 0.1 μm) due to the high temperatures of these processes. Lead particles emitted by handling and mechanical processes (e.g., ore processing) are several times larger (i.e., greater than 2 microns) than particles emitted by combustion or smelting sources. Larger particles are removed from the air by deposition close to the source, while smaller-sized particles are transported over long distances.

If the ministry reponsible for air monitoring has no experience in ambient air sampling, advice on the appropriate and practical methods should be sought from one of the institutions offering technical assistance (see Table 6 in Chapter 3)

7.1 Collection of Lead Particulates in Air Samples

The simplest method for collecting particulate lead samples in ambient air to monitor the phase-out of lead in gasoline is to rely on existing air particulate sampling methods and equipment used by the relevant ministry (e.g., Ministry of Environment).

Ambient air sampling is commonly done using high-volume or low-volume air samplers (for example, dichotomous samplers, TSP samplers or PM_{10} samplers). However, high-volume samplers are still the recommended method for collecting lead ambient air samples. High-volume air samplers capture 80 to 90% of the total mass of lead, and collect on average twice as much lead mass as PM_{10} samplers. The PM_{10} sampler excludes particles larger than the respirable size, which makes a major difference in sampling since exposure to lead occurs through inhalation and ingestion of particles that are too large to be inhaled. Therefore, the high-volume sampler provides a more complete assessment of exposure to ambient lead than the PM_{10} sampler. The high-volume sampler is simpler and less expensive to operate, and the results obtained may be easier to compare with measurements collected in other parts of the world.

Sampling should be conducted at carefully selected sites. Sites to be considered include areas near heavily trafficked city streets, work sites associated with the survey of occupationally exposed workers, elementary school playgrounds, day-care facilities or neighborhoods of women surveyed at time of delivery. If possible, sites should be selected with the purpose of this study in mind; therefore, sites close to lead-emitting industries should be avoided. Within a few hundred meters of any potential source, the particle size distribution of lead stabilizes and remains roughly constant thereafter with transport into remote environments. According to U.S. EPA (EPA 1997), lead samplers should be placed to obtain a representative measurement of the lead concentration in the

area of concern. Because the sampling area will be of neighborhood-wide areas, the sampler inlet should be located 2 to 15 meters above ground level. Since nearby buildings can create downwash and turbulent effects, the distance between the sampler and any obstacles must be at least twice the height that the obstacle protrudes above the sampler. There must be an unrestricted airflow in an arc of at least 270 degrees around the sampler for the season with the greatest pollutant concentration. The sampler should not be placed near any furnaces or incinerator flues. Any tree(s) that act as obstructions between the source of the lead emissions and the sampler should be at least 10 meters distant.

Samplers for monitoring ambient air should be operated at a minimum schedule of once every 6 days; the frequency may be increased to obtain a more complete database. A finer time resolution than 24-hours is not likely to provide useful information. The final sampling schedule will depend on budgetary issues, however, the minimum recommended schedule is one-in-six days over a 5 to 10 year period.

Another sampling method that can be used is field-portable anodic stripping voltammetry (ASV). A protocol for this approach is found in the American Society for Testing and Materials (ASTM) Standard E 1775-96 (see Appendix F) published in 1996, and is also described by Ashley (1995, 1998).

7.2 Laboratory Analysis of Lead Particulates in Air Samples

The reference method procedure for determining lead in suspended particulate matter collected from ambient air requires that the lead be solubilized using extraction procedures involving nitric acid (HNO) and hydrochloric acid (HCl), with subsequent analysis using atomic absorption spectrometry. Individual filter samples or composites of as many as eight filter samples collected over a consistent one-week, two-week, or one-month period during a calendar month may be analyzed for lead content to derive a monthly average concentration. EPArecommends the use of eight filters for compositing.

One protocol for sample preparation and analysis is found in ASTM Standard E 1613, Test Method for Analysis of Digested Samples for Lead by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Flame Atomic Absorption (FAA), or Graphite Furnace Atomic Absorption. Assistance with laboratory analysis of environmental samples and environmental lead proficiency testing is available; see Table 6 for details.

Special Methods: Source Determination

Highly sophisticated techniques such as lead isotopic analysis are designed to identify the probable sources of certain lead compounds in the environment. The lead isotope methodology is based on the fact that lead consists of four natural stable isotopes which vary in relative abundance from one lead ore to another. Therefore, the relative abundance of these isotopes in any given lead particles provides a fingerprint of the lead from a particular source. Since the isotopic ratios remains constant, it is possible to measure differences in lead isotope ratios between different sources and to use this information to evaluate the impact of potential sources of exposure (see Silbergeld 1996 for further discussions). The technique is used to distinguish lead originating from specific mines in certain regions of the world. According to Dr. E Silbergeld (personal communication, 1996), much of the lead in gasoline sold in the Americas comes from one particular mine in Australia, which has a

specific lead isotope ratio (i.e., isotopic composition); other lead mines in other sites in the world have different lead isotope ratios. The relative ratio of lead particulates derived from gasoline vs. lead smelters or other heavy industry was recently demonstrated in an air paticulates source apportionment study in Cairo, Egypt (Rodes et al. 1996).

With sufficient background information on lead sources, a few representative ambient air samples measured by lead isotopic analysis could demonstrate the shift in the relative proportions (contributions) of lead from different sources (e.g., gasoline vs. other sources) in a country (see Tera et al. 1985)

7.3 Data Completeness and Reporting Requirements

In the United States, the current recommended value for ambient air lead is 1.5 $\mu g/m^3$. A quarterly average concentration of greater than 1.5 $\mu g/m^3$ is considered to exceed the standard. At least 75% of the lead samples must be available for the quarterly average to be considered valid. In addition, the interval must be long enough to allow collection of sufficient valid samples for statistical integrity of the data.

7.4 Data Analysis

As a first step, the goal should be to identify climatic factors that influence lead levels. For example prevailing wind direction, height and magnitude of inversions (daytime and nocturnal), season of the year (rainy vs. dry period, summer vs. winter). A recommended strategy is to examine the frequency distribution of lead levels and then to conduct a time-series analysis with case studies for peak values. Graphical presentation of trends by time is useful for revealing the nature of any tendency. Graphical presentation of two or more variables plotted simultaneously against time may also be useful for identifying relations between lead levels and other variables. Regression analysis can be used to further explore and quantify apparent relationships. Reporting should include the percentile distribution of lead values per quarter. The proportion of time averages that exceed the recommended value of 1.5 $\mu g/m^3$ should be reported.

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APPENDIX A: Members of EHP Technical Review Panel

Dr. Sherry Baron, ECO/PAHO, Pan American Center for Human Ecology and Health, Cuernavaca, Morelos, Mexico and Centers for Disease Control and Prevention, Atlanta, Georgia

Dr. John Borrazzo, Environmental Health Advisor, Office of Health and Nutrition, U.S. Agency for International Development, Washington, D.C.

Dr. Howard Frumpkin, Chair, Dept. Environmental and Occupational Health, School of Public Health, Emory University, Atlanta, Georgia

Dr. Luiz A.C. Galvão, Regional Advisor, Environmental Quality Program, Health and Environment Division, PAHO/WHO, Washington, D.C.

Dr. Tom Matte, National Center for Environmental Health, Office of the Director, Centers for Disease Control and Prevention, Atlanta, Georgia

Dr. Robert McConnell, Mount Sinai Hospital, New York

Dr. Carol Pertowski, National Center for Environmental Health, Surveillance and Programs Branch, Centers for Disease Control and Prevention, Atlanta, Georgia

Ing. Cor P.W. van der Sterren, Oil and Gas Division, Industry and Energy Department, World Bank, Washington, D.C.

APPENDIX B: List of LAC Laboratories Currently Enrolled in CDC PAT Program

SL 5516
University of the West Indies
Dr Ivan Chang Yen
Department of Chemistry
St Augustine
Trinidad & Tobago West Indies
◉ LM ○ PB ○ EP Special LM2
Reference Lab ○ YES

SL 5518
ABC Hospital
Dr Terres
Sur 136 Esq Observatorio
Mexico City 01210 D Mexico

◉ LM ○ PB ◉ EP Special Dhl
Reference Lab ○ YES

SL 5523
Univ Nacional Autonoma de Mexico
Dr Dolores De La Cruz
Apart Post 0920 JC Bon 66
Col Ejercito de Oriente
Del Iztap 09230 CP Mexico
◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5525
INNYN
Dr Manuel Velasco
Ave Insurgentes Sur No 3877
Mexico City 22 DF Mexico

◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5598
Unidad de Investigacion
Dr Miguel Zuniga Charles
San Luis Potosi Y 2 De Abril
Col Independ AP 020 E
Monterrey 64720 NL Mexico
◉ LM ○ PB ○ EP Special LM2
Reference Lab ○ YES

SL 5599
Instituto de Salud Publica
Lab de Salud Ocupacional
Av Marathon #1000
Santiago Chile

◉ LM ○ PB ◉ EP Special No Commercial Value
Reference Lab ○ YES

SL 5600
Laboratoria de Toxicoligia Ambiental
Facultad de Medicina Universidad Autonoma de S L P
Av Venustiano Carranza #2405 Col Lomas los Filtros
San Luis Potosi Mexico

◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5603
Envirolabs Inc
Dr Adolfo Valdes Agrait
Sabanetas Industrial Park
PO Box 59
Mercedita PR 00715
◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5609
Toxiclin Laboratorio
535 Rio Comprido
Rua Santa Alexandrina
Rio De Janeiro CEP RJ Brasil

◉ LM ○ PB ○ EP Special LM2
Reference Lab ○ YES

SL 5610
Microanalisis Toxicologicos SA
Dr Pablo Junco-Munoz
J Cantu Leal 2551
Monterrey 64830 NL Mexico

◉ LM ○ PB ○ EP Special lm2 ep2
Reference Lab ○ YES

SL 5611
Natl Diagnostic & Ref Center
Dr Carlos Morales Bonilla
PO Box 5192
Managua Nicaragua

◉ LM ○ PB ○ EP Special lm2
Reference Lab ○ YES

SL 5516
University of the West Indies
Dr Ivan Chang Yen
Department of Chemistry
St Augustine
Trinidad & Tobago West Indies
◉ LM ○ PB ○ EP Special LM2
Reference Lab ○ YES

SL 5722
Met-Mex Penoles SA DE CV
Dr Guillermo Ortiz R
Apartado Postal 93
Torreon Coah 27370 CP Mexico

◉ LM ○ PB ○ EP Special lm2
Reference Lab ○ YES

SL 5518
ABC Hospital
Dr Terres
Sur 136 Esq Observatorio
Mexico City 01210 D Mexico

◉ LM ○ PB ◉ EP Special Dhl
Reference Lab ○ YES

SL 5940
Instituto Mex Del Seguro Social
Dr Norma D Arrieta Alcalde
Lab de Salud en el Trabajo
Monterrey 64720 NL Mexico

◉ LM ○ PB ○ EP Special lm2
Reference Lab ○ YES

SL 5523
Univ Nacional Autonoma de Mexico
Dr Dolores De La Cruz
Apart Post 0920 JC Bon 66
Col Ejercito de Oriente
Del Iztap 09230 CP Mexico
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Reference Lab ○ YES

SL 5947
CEHISI
Dr Robson Vieira de Figueiredo
Rua Pedro Alves 14
20220-281 Santo Cristo
Rio de Janeiro RJ Brasil
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Reference Lab ○ YES

SL 5525
INNYN
Dr Manuel Velasco
Ave Insurgentes Sur No 3877
Mexico City 22 DF Mexico

◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 6179
Asociacion Chilena de Seguridad
Dr Maria Luisa Coopman Barros
Industrial Hygiene Laboratory
Vicuna Mackenna 200 Piso 2
Santiago Chile
◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5598
Unidad de Investigacion
Dr Miguel Zuniga Charles
San Luis Potosi Y 2 De Abril
Col Independ AP 020 E
Monterrey 64720 NL Mexico
◉ LM ○ PB ○ EP Special LM2
Reference Lab ○ YES

SL 5599
Instituto de Salud Publica
Lab de Salud Ocupacional
Av Marathon #1000
Santiago Chile

◉ LM ○ PB ◉ EP Special No Commercial Value
Reference Lab ○ YES

SL 5600
Laboratoria de Toxicoligia Ambiental
Facultad de Medicina Universidad Autonoma de S L P
Av Venustiano Carranza #2405 Col Lomas los Filtros
San Luis Potosi Mexico

◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5603
Envirolabs Inc
Dr Adolfo Valdes Agrait
Sabanetas Industrial Park
PO Box 59
Mercedita PR 00715
◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

SL 5609
Toxiclin Laboratorio
535 Rio Comprido
Rua Santa Alexandrina
Rio De Janeiro CEP RJ Brasil

◉ LM ○ PB ○ EP Special LM2
Reference Lab ○ YES

SL 5610
Microanalisis Toxicologicos SA
Dr Pablo Junco-Munoz
J Cantu Leal 2551
Monterrey 64830 NL Mexico

◉ LM ○ PB ○ EP Special lm2 ep2
Reference Lab ○ YES

SL 5611
Natl Diagnostic & Ref Center
Dr Carlos Morales Bonilla
PO Box 5192
Managua Nicaragua

◉ LM ○ PB ○ EP Special lm2
Reference Lab ○ YES

SL 5722
Met-Mex Penoles SA DE CV
Dr Guillermo Ortiz R
Apartado Postal 93
Torreon Coah 27370 CP Mexico

◉ LM ○ PB ○ EP Special lm2
Reference Lab ○ YES

SL 5940
Instituto Mex Del Seguro Social
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Monterrey 64720 NL Mexico

◉ LM ○ PB ○ EP Special lm2
Reference Lab ○ YES

SL 5947
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Reference Lab ○ YES

SL 6179
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Industrial Hygiene Laboratory
Vicuna Mackenna 200 Piso 2
Santiago Chile
◉ LM ○ PB ○ EP Special
Reference Lab ○ YES

APPENDIX C: List of LAC/PAHO Lab Network Members

LABORATORIOS PARTICIPANTES, RESPONSABLES Y DIRECCIÓN POR PAÍS

PAÍS	LABORATORIO	RESPONSABLE
Argentina	Laboratorio de Toxicología y Química Legal Facultad de Farmacia y Bioquímica Junin 956, 113 Buenos Aires Tels. 962-3822/962-3414	Ing. Clara López
Bolivia	Laboratorio de Aguas Facultad de Ciencias y Tecnología Casilla 5783, Cochabamba Tel. (042) 506-60 Fax. (042) 317-65	Lic. Ana María Romero
	Laboratorio Espectrolab Universidad Técnica de Oruro Casilla 252 - Ciudad Universitaria, Oruro Tel. (591) 52-60850 Fax. (591) 52-60850	Ing. Herbert Guevara
Brasil	Laboratorio de Metales Instituto Adolfo Lutz Av. Dr. Arnaldo 355 São Paulo 01246-902	Dra. Alice Sakuma
	Laboratorio de Toxicología Facultad de Farmacia de UFBA-Bahía Rua Leopoldo Bulhoes, 1480 Manguinhos Rio de Janeiro-RJ 21041-210 Tel. (21) 230-1050 Fax: (21) 270-3219	Dr. Eustaquio Borges Linhares
	Laboratório de Radioisótopos Eduardo Penna Franca Instituto de Biofísica Carlos Chagas F° Universidade Federal do Rio de Janeiro Centro de Ciências da Saúde-BLC.G CEP 21941 - Rio de Janeiro RJ Tel. (55-21) 590-7147, 280-8093 Fax. 2808193, 2804694 Internet: olaf@ibccf.biof.ufrj.br	Dr. Olaf Malm
Costa Rica	Laboratorio del Instituto Costarricense de Investigación y Enseñanza en Nutrición y Salud Tres Rios-Cartago, Apartado Postal 04 Tel. (506) 220-7593 Fax. (506) 231-4701	Lic. Thelma Alfaro
Chile	Laboratorio de Descontaminación Ambiental e Higiene Industrial Instituto Nacional de Salud Avda. Maratón N° 1000, Comuna de Ñuñoa, Santiago Tel. 239-1105, anexo 706 Fax. 239-3600	Lic. Wilfrido Zavala P.

PAÍS	LABORATORIO	RESPONSABLE
México	Laboratorio de Toxicología Ambiental - UASLP Av. Venustiano Carranza N° 2405 San Luis Potosí, S.L.P. 78210 Tel. (48) 13-04-99 Fax. (48) 17-69-76	Dr. Jesús Mejía
	Laboratorio de Toxicología Analítica - CINVESTAV Av. Instituto Politécnico N° 2508, Col. San Pedro Zacatenco, 07000 México, D.F. Tel. 747-7000, 7001 conmutador Fax. 747-7095 Directo, 747-7002	M. en C. María de la Luz Del Raso
Perú	Laboratorio del CEPIS/OPS Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente - CEPIS Calle Los Pinos 259, Urbanización Camacho, Lima 12 Tel. (51-14) 371-077/377-081 Fax. (51-14) 378-289	Dra. María Luisa Esparza
Trinidad y Tobago	Analytical Chemistry Laboratory Department of Chemistry-University of West Indies St. Angustine, Trinidad, W.I. Tel. (809) 663-1364/1374 Fax. (809) 663-9685	Dr. Ivan Chang-Yen
Venezuela	Laboratorio de Salud Ocupacional y Contaminación Atmosférica Edificio Sur Centro Simón Bolívar 3er Piso, Edif. 210, Caracas Fax. (58-2) 482-5529	Ing. Albrech Müller

APPENDIX D: Sample Questionnaires

The sample questions presented in this appendix are not intended to be comprehensive. The objective is to illustrate, with some examples, the types of questions needed to assess risk factors for lead exposure for the target populations discussed in this document: occupationally exposed workers, children and pregnant women. The precise wording and most appropriate questions would need to be developed on a site-specific basis.

SAMPLE QUESTIONS FOR OCCUPATIONALLY EXPOSED POPULATIONS

I General Information

Participant Identification Number _____

Interviewer code _____

Date of interview _____/_____/_____
(Month/Day/Year)

What is your date of birth? _____/_____/___
(Month/Day/Year)

Current Address: _____
(Number, Street, or Rural Route)
_____

_____
(City or Town, State, Zip Code)

Gender:
1. Male
2. Female

List two persons that we could call if we need to contact you?

Person #1:
Name
Address
Telephone

Person #2:
Name
Address
Telephone

Do you know how to read?
1 Yes 2 No

Do you know how to write?
1 Yes 2 No

Have you ever attended school?
1 Yes 2 No

What is the highest level of school that you completed?

Primary: 1st grade
2nd grade
3rd grade
4th grade
5th grade
6th grade

Secondary school (lower): 1st year
2nd year
3rd year

Secondary school (upper): 4th year
5th year
6th year

Other technical school (specify) _____

University (# of years) _____

Postgraduate school (# of years)_____

What is the principal source of drinking water at your home?

1 Piped inside for family use only
2 Piped outside the house for family use only
3 Piped inside for all uses
4 Bottled water
5 A well or pond
6 Water from government or private trucks
7 Other (specify) _____

II Information Regarding Smoking

Have you ever smoked cigarettes? 1 Yes 2 No

Have you smoked at least as many as five packs of cigarettes, that is, 100 cigarettes during your entire life? 1 Yes 2 No

Do you NOW smoke cigarettes? 1 Yes 2 No

How old were you when you started smoking cigarettes regularly?
(age in years)_____

How much do you smoke on the average? (cigarettes/day)_____

Do you inhale the cigarette smoke? 1 Yes 2 No

Do you smoke at work? 1 Yes 2 No

When you smoke at work, how often do you wash your hands before smoking?

1 Often

2 Sometimes
3 Rarely
4 Never
9 Unknown

During the last 30 days have you:

1 Decreased the number of cigarettes you smoke at home?
2 Increased the number of cigarettes you smoke at home?
3 Decreased the number of cigarettes you smoke at work?
4 Increased the number of cigarettes you smoke at work?

III Dietary Habits

Do you eat at your work place?

How often do you wash your hands before eating?

1 Often
2 Sometimes
3 Rarely
4 Never
9 Unknown

Do you eat snacks at work? 1 Yes 2 No

How often do you wash your hands before eating snacks at work?

1 Often
2 Sometimes
3 Rarely
4 Never
9 Unknown

IV Work Characteristics

What is your occupation?

When did you start working in this occupation?

____ _____
Year Month

Describe your job duties during the past month _____

Have your job duties changed in the last month?

1 Yes (specify) _____
2 No

Has the change in duties increased or decreased your exposure to vehicular fumes?

1 Increased
2 Decreased

How clean is your workspace area?

1 Very clean
2 Reasonably clean
3 Somewhat dusty or dirty
4 Very dusty or dirty

In a typical work situation this past month:

How many days a week did you work? _____
How many hours a day did you work? _____

On average, how much physical activity is involved in your work?

1 Extensive (you are moving all the time)
2 Moderate
3 Mild
4 None (you are sitting all the time)

Do you use special clothes (uniform) at work? 1 Yes 2 No

Who is responsible for the cleaning of your work clothes?

1 You, at your home
2 You, outside your house
3 The company

V Exposure to Vehicular Traffic

How would you rank your overall exposure to road traffic?

1 Very high
2 High
3 Medium
4 Low
5 None

In a typical day this past month:

How much time did you spent outdoors in recreational activities? _____(hours)
How much time did you spent using public transportation? _____(hours)

When you use public transportation are you exposed to vehicular traffic?

1 No
2 Yes, to low intensity traffic
3 Yes, to medium intensity traffic
4 Yes, to high intensity traffic

What type of transportation do you use more frequently?

1 Your car
2 Taxi
3 Mini bus
4 Bus
5 Bicycle
6 Walk most of the time

Which situation best describes the street where your home is located?

1 Constant traffic
2 Medium traffic
3 Low traffic
4 Almost no traffic

VI Exposure From Other Sources

Is your home is located near to an industrial zone? 1 Yes 2 No

Is your home is located near to any mining area or storage area for ores or concentrates?

1 Yes 2 No

Is your home is located near to a smelter? 1 Yes 2 No

Have you had contact with gasoline in the last 30 days (For example did you use gasoline to clean you hands or any other objects?) 1 Yes 2 No

Before this job, did you worked in any of the following occupations:

Lead smelter worker
Foundry worker
Oil refinery worker
Painter
Battery plant worker
Chemical plant worker
Paint pigment, zinc copper Worker
Plumber
Glass worker
Production of lead-glazed ceramics
Other industries related to lead

Do you have any of the following habits?

Bite or suck pencils at work

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Bite your nails

1 Almost every day 2 sometimes 3 almost never 9 Unknown

SAMPLE QUESTIONS FOR CHILDREN

I General Information

Name _____

Participant Identification Number _____

Birth Date: _____/_____/_____
(Month/Day/Year)

Current Address: _____
(Number, Street, or Rural Route)

_____
(City or Town, State, Zip Code)

Gender: **1 Male**
2 Female

II Exposure

In a typical sunny week this past month, did (child s name) spend any time playing outside in areas around the house such as the porch, sidewalk or street?

1 Yes
2 No
9 Unknown

How many days per week did (he/she) usually play there?

1 One day
2 Two days
3 Three days
4 Four days
5 Five days
6 Six days
7 Everyday
9 Unknown

This past month, how many hours a day did (he/she) usually spend on the porch, sidewalk or street?
_____ (hours)

This past month did (child s name) ever take a pacifier with (him/her) when (he/she) played outdoors?

1 Yes
2 No
9 Unknown

About how often did (he/she) do this?

1 At least once per day
2 At least once per week but not everyday
3 A few times a month
4 Once per month or less
9 Unknown

This past month did (child s name) ever take a baby bottle with (him/her) when (he/she) played outdoors?

1 Yes
2 No
9 Unknown

About how often did (he/she) do this?

1 At least once per day
2 At least once per week but not everyday
3 A few times a month
4 Once per month or less
9 Unknown

This past month did (child s name) ever eat food when (he/she) played outside?

1 Yes
2 No
9 Unknown

About how often did (he/she) do this?

1 At least once per day
2 At least once per week but not everyday
3 A few times a month
4 Once per month or less
9 Unknown

This past month when (child s name) was inside at home, how often did (he/she) play or sit on the floor?

1 Often
2 Sometimes
3 Almost never
9 Unknown

About how many hours on an average day do you think (child s name) usually sat or played on the floor at home? _____(hours)

How often does (child s name) suck (his/her thumb or fingers? Would you say often, sometimes, rarely, or never?

1 Often
2 Sometimes
3 Rarely
4 Never
9 Unknown

Have you ever seen (child s name) eat dirt or sand?

1 Yes
2 No

Does (child s name) have a favorite blanket or stuffed toy?

1 Yes
2 No
9 Unknown

How often are (child s name) hands washed before eating meals?

1 Almost always
2 sometimes
3 almost never
9 Unknown

How often are (his/her) hands washed after eating meals?

1 Almost always
2 sometimes
3 almost never
9 Unknown

How often are (child s name) hands washed before eating snacks?

1 Almost always
2 sometimes
3 almost never
9 Unknown

How often are his/her hands washed after eating snacks?

1 Almost always
2 sometimes
3 almost never
9 Unknown

How often are (his/her) hands washed after playing outdoors?

1 Almost always
2 sometimes
3 almost never
9 Unknown

In the previous month, have you seen your child do the following?

Eat dirt

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Bite or suck pencils

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Bite or suck clay

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Bite or suck crayons

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Bite or suck toys

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Eat paint off the walls

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Put his/her hands in his/her mouth

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Suck his/her fingers

1 Almost every day 2 sometimes 3 almost never 9 Unknown

Bite his/her nails

1 Almost every day 2 sometimes 3 almost never 9 Unknown

When your child goes to school, what type of transportation does he/she use?

1 Bus
2 Taxi
3 Private vehicle
4 Bicycle
5 Walks

If your child uses public transportation, how many minutes does he/she wait in the street?

_____ (minutes)

Which situation best describes the street where the home of (child s name) is located?

1 Street with constant traffic
2 Street with medium traffic
3 Street with low traffic
4 Street with almost no traffic

Which situation best describes the street where the home of (child s name) is located?

1 Paved street
2 Unpaved

Is the father of (child s name) working in any of the following occupations?

1 Lead smelter worker
2 Foundry worker

3 Oil refinery worker
4 Painter
5 Battery plant worker
6 Chemical plant worker
7 Paint pigment, zinc, copper worker
8 Plumber
9 Glass worker
10 Production of lead-glazed ceramics
11 Radiator repair shop
12 other industries related to lead, (specify)_____

If yes, ask: Where are the father s work clothes washed?
1 At home
2 At work

Do you or your husband do any of the following activities at home or in a place near home, such as in the backyard?

1 Plumbing
2 Car battery repair
3 Car battery recycling
4 Radiator repair
5 Use of gasoline
6 Any other activity related to lead

If yes, ask: How often does (child s name) play close to this area?
1 Almost every day
2 Sometimes
3 Almost never
9 Unknown

Are his/her hands almost always, sometimes or almost never washed after eating snacks?

1 Almost always
2 sometimes
3 almost never
9 Unknown

When the child plays outdoors? Are (his/her) hands almost always, sometimes or almost never washed after playing outdoors?

1 Almost always
2 sometimes
3 almost never
9 Unknown

At bed time Are (his/her) hands almost always, sometimes or almost never washed after playing outdoors?

1 Almost always
2 sometimes
3 almost never
9 Unknown

In the previous month, have you seen in your child doing the following?

Eat dirt
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Bite or suck pencils
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Bite or suck clay
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Bit or suck crayons
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Bite or suck toys
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Eat pain of the walls
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Put his/her hands in his/her mouth
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Suck his/her fingers
1 Almost every day 2 sometimes 3 almost never 9 Unknown
Bite his/her nails
1 Almost every day 2 sometimes 3 almost never 9 Unknown

When your child goes to school what type of transportation does he/she uses?

1 Bus
2 Taxi
3 Private vehicle
4 Bicycle
5 Walks

Which situation describes better the street where the home of (child s name) is located:

1 Street with constant traffic
2 Street with medium traffic
3 Street with low traffic
4 Street with almost no traffic

Which situation describes better the street where the home of (child s name) is located:

1 Paved street
2 Unpaved

Is the father of (child s name) working in any of the following occupations:

Lead smelter worker
Foundry worker
Oil refinery worker
Painter
Battery plant worker
Chemical plant worker
Paint pigment, zinc copper Worker
Plumber
Glass worker
Production of lead-glazed ceramics
Other industries related to lead

If yes, ask who washed the clothes

Working clothes are washed at home
Working clothes are washed at work

Do you or your husband do any of the following activities at home or in a place near home, for example in the backyard?

Plumbing
Car battery repair
Car battery recycling
Radiator repair
Use of gasoline
Any other activity related to lead

If yes ask the following question:
How often does (child s name) plays close to this area?

1 Almost every day 2 sometimes 3 almost never 9 Unknown

APPENDIX E: Whole Blood Collection and Processing

WHOLE BLOOD COLLECTION AND PROCESSING

NOTE: Universal Precautions- procedures to prevent exposure to HIV, hepatitis, etc., are ASSUMED during all collection and handling of biological specimens. ALL specimens should be considered POTENTIALLY INFECTIOUS- see CDC Guidelines for specific recommendations and procedures.

Whole blood collection procedure

1. Materials needed:

- Gauze sponges
- Alcohol wipe
- Band-Aid
- 3 ml purple-top tube
- 21g 3/4 butterfly assembly with multiple sample Luer adapter, sterile
- 23g 3/4 butterfly assembly with multiple sample Luer adapter for children and difficult sticks
- 21g or 22g Vacutainer multiple sample needles
- 5cc plastic syringe for children
- Preprinted labels
- Tourniquet
- Vacutainer holder and adapters for pediatric tubes (if children are going to be sampled)
- Refrigerator
- White storage boxes

2. Venipuncture procedure:

- Locate a suitable table and chair for blood collecting and lay out blood collection supplies
- Locate the puncture site. Hold with 2 fingers on one side of the alcohol wipe so that only the other side touches the puncture site. Wipe the area in a circular motion beginning with a narrow radius and moving outward so as not to cross over the area already cleaned. Repeat with a second alcohol wipe.
- Locate the vein and cleanse in manner previously described, then apply the tourniquet. If it is necessary to feel the vein again, do so; but after you feel it, cleanse with alcohol prep again, and dry with a sterile gauze square.
- Fix the vein by pressing down on the vein about 1 inch below the proposed point of entry into the skin and pull the skin taught.
- Approach the vein in the same direction the vein is running, holding the needle so that it is at an approximately 15 degree angle with the examinee s arm.

•Push the needle, with bevel facing up, firmly and deliberately into the vein. Activate the vacuum collection tube. If the needle is in the vein, blood will flow freely into the tube. If no blood enters the tube, probe for the vein until entry is indicated by blood flowing into the tube.
•For collection, loosen the tourniquet immediately after blood flow is established and release entirely as the last tube fills. Collect 1 purple-top tube (3 ml).
•If a syringe is required to obtain the blood, attach it to the appropriate size butterfly needle and withdraw 2-3 mls blood. After withdrawing the needle from the arm, quickly change the needle on the syringe and transfer the blood from the syringe by puncturing the top of the purple-top tube with the new needle and allowing the vacuum to draw the blood into the tube.
•Mix well with the anticoagulant.
•When the needle is out of the arm, press gauze firmly on the puncture. Heavy pressure as the needle is being withdrawn should be avoided because it may cause the sharp point of the needle to cut the vein.
•Have the examinee raise his arm (not bend it) and continue to hold the gauze in place for several minutes. This will help prevent hematomas.
•Report to the physician any reaction experienced by the participant during the venipuncture procedure.
•Label all tubes with the preprinted labels provided, and use a ballpoint pen to add the date collected and your initials to the label. The tubes should be affixed with the label showing the participant s ID number (e.g. 92-0024-0001-B1).
•Place a Band-Aid on the subject s arm.

TECHNIQUE FOR CAPILLARY (FINGERSTICK) LEAD SAMPLING

NOTE: Universal Precautions- procedures to prevent exposure to HIV; hepatitis, etc., are ASSUMED during all collection and handling of biological specimens. ALL specimens should be considered POTENTIALLY INFECTIOUS- see CDC Guidelines for specific recommendations and procedures.

1. Materials needed per participant:

    •Gauze sponges
    •Examination loves
    •Alcohol wipe
    •Band-Aid
    •Blood collection capillary tube
    •Lancing device with built-in needle protector
    •Preprinted labels
    •Appropriate waste containers

2. Finger stick procedure:

    •Locate a suitable table and chair for blood collecting and lay out blood collection supplies
    •Thoroughly wash participant hands with soap and warm water. Warming the puncture site will increase blood flow
    •Wear examination globes
    •Select the middle or the ring finger and massage gently the fleshy part of the finger

•Clean the finger pad to be punctured with an alcohol swab; dry with a sterile gauze or a cotton ball.
•Puncture the finger or the heel in infants younger than 1 year
•Grasp the finger and quickly puncture it with a sterile lancet
•For the puncture, choose a spot near the fingertip and puncture the side of the finger near the tip.
•Squeeze gently around the puncture site to obtain a large drop of blood. Wipe this first drop of blood off with a clean gauze or cotton ball
•Do not let blood run down to the finger or onto the fingernail
•Continue to grasp the finger, touch the tip of the collection container to the beaded drop of blood, when the container is full cap or seal the container
•Agitate the container to mix the anticoagulant through the blood
•If collecting with capillary tubes, squeeze gently the finger while holding it down to form a large drop of blood
•Position the capillary with the tapered en towards the drop of blood.
•Hold the capillary horizontally or with the end away from the finger slightly elevated. Fill the capillary with blood to the indicator mark.
•Wipe remaining blood from the finger. With clean gauze apply pressure until bleeding stops.
•Do not let the blood sample in the capillary more than 5 minutes.
•Label all tubes or collection control papers with the preprinted labels provided, and use a ballpoint pen to add the date collected and your initials to the label. The tubes should be affixed with the label showing the participant s ID number (e.g. 92-0024-0001-B1).
•Place a Band-Aid on the subject s finger

Common causes of falsely high values include:

•Failure to wipe the first drop of blood
•Failure to use examination gloves
•Inadequate cleansing of child s finger
•Bubbles or gaps in collection tubes
•Touching of the end of capillary or collection tubes

References:

•Screening for Elevated Blood Lead Levels. Pediatrics. 101(6):1072-1078.1998.
•LeadCare Blood testing System User s Guide, Rev E

PROCEDURE TO OBTAIN UMBILICAL CORD BLOOD SAMPLE

NOTE: Universal Precautions - procedures to prevent exposure to HIV, hepatitis, etc., are ASSUMED during all collection and handling of biological specimens. ALL specimens should be considered POTENTIALLY INFECTIOUS - see CDC Guidelines for specific recommendations and procedures.

1. Materials needed:

•Gauze sponges
•Alcohol wipes
•3 ml purple-top tube
•21g 3/4 butterfly assembly with multiple sample Luer adapter, sterile
•23g 3/4 butterfly assembly with multiple sample Luer adapter for children and difficult sticks
•21g or 22g Vacutainer multiple sample needles
•5cc plastic syringe for children
•Preprinted labels
•Tourniquet
•Vacutainer holder and adapters
•White storage boxes

2. Umbilical cord venipuncture procedure:

•Locate a suitable table and recipient to receive the placenta.
•Inform the attending physician that you collect a sample of umbilical cord blood. This is important so that the cord will remain clamped when the placenta is extracted.
•Locate the puncture site. Hold with 2 fingers on one side distal to the clamp site and close to the placenta. Wipe and clean well the area in a circular motion beginning with a narrow radius and moving outward so as not to cross over the area already cleaned. Repeat with a second alcohol wipe.
•Locate the vein
•Fix the vein by pulling the cord down on the vein about 1 inch below the root of the placenta, locate a point of entry into the cord
•You can apply a little pressure in the placenta to load the veins
•Approach the vein in the same direction the vein is running, holding the needle so that it is at an approximately 15-degree angle with the cord.
•Push the needle, with bevel facing up, firmly and deliberately into the vein. Activate the vacuum collection tube. If the needle is in the vein, blood will flow freely into the tube. If no blood enters the tube, probe for the vein until entry is indicated by blood flowing into the tube.
•Collect 1 purple-top tube (3 ml).
•If a syringe is required to obtain the blood, attach it to the appropriate size butterfly needle and withdraw 2-3 ml blood. After withdrawing the needle from the arm, quickly change the needle on the syringe and transfer the blood from the syringe by puncturing the top of the purple-top tube with the new needle and allowing the vacuum to draw the blood into the tube.
•Mix well with the anticoagulant.
•Discharge the placenta
•Labels all tubes with the preprinted labels provided, and use a ballpoint pen to add the date collected and your initials to the label. The tubes should be affixed with the label showing the participant s ID number (e.g. 92-0024-0001-B1).

Appendix F: Standard Guide for Evaluating Performance of On-Site Extraction and Field-Portable Electrochemical or Spectrophotometric Analysis for Lead (ASTM etc.)

Designation: E 1775 - 96

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Guide for Evaluating Performance of On-Site Extraction and Field-Portable Electrochemical or Spectrophotometric Analysis for Lead[1]

This standard is issued under the fixed designation E 1775; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard provides guidelines for determining the performance of field-portable quantitative lead analysis instruments.

1.2 This guide applies to field-portable electroanalytical and spectrophotometric (including reflectance and colorimetric) analyzers.

1.3 Sample matrices of concern herein include paint, dust, soil, and airborne particulate.

1.4 This guide addresses the desired performance characteristics of field-based sample extraction procedures for lead, as well as on-site extraction followed by field-portable analysis.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 5438 Practice for Collection of Floor Dust for Chemical Analysis[2]

E 1553 Practice for Collection of Airborne Particulate Lead During Abatement and Construction Activities[2]

E 1583 Practice for Evaluating Laboratories Engaged in Determination of Lead in Paint, Dust, Airborne Particulates, and Soil Taken from and around Buildings and Related Structures[2]

E 1605 Terminology Relating to Abatement of Hazards from Lead-Based Paint in Buildings and Related Structures[2]

E 1613 Test Method for Analysis of Digested Samples for Lead by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Flame Atomic Absorption (FAAS), or Graphite Furnace Atomic Absorption (GFAAS) Techniques[2]

E 1644 Practice for Hot Plate Digestion of Dust Wipe Samples for Determination of Lead by Atomic Spectrometry[2]

E 1645 Practice for Preparation of Dried Paint Samples for Subsequent Lead Analysis by Atomic Spectrometry[2]

E 1726 Practice for Sample Digestion of Soils for Determination of Lead by Atomic Spectrometry[2]

E 1727 Practice for Field Collection of Soil Samples for Lead Determination by Atomic Spectrometry Techniques[2]

E 1728 Practice for Field Collection of Settled Dust Samples Using Wipe Sampling Methods for Lead Determination by Atomic Spectrometry Techniques[2]

E 1729 Practice for Field Collection of Dried Paint Samples for Lead Determination by Atomic Spectrometry Techniques[2]

E 1741 Practice for Preparation of Airborne Particulate Lead Samples Collected During Abatement and Construction Activities for Subsequent Analysis by Atomic Spectrometry[2]

2.2 *U.S. EPA Documents:*

EPA 600/R-93/200 Standard Operating Procedure for the Field Analysis of Lead in Paint, Bulk Dust, and Soil by Ultrasonic, Acid Digestion and Colorimetric Measurement (1993)[3]

EPA 747-R-92-001 Laboratory Accreditation Guidelines: Measurement of Lead in Paint, Dust, and Soil (1992)[4]

3. Terminology

3.1 For definitions of terms not listed here, see Terminology E 1605.

3.2 *anodic stripping voltammetry*—an electroanalytical technique in which the concentration of analyte metal species dissolved in solution is determined in the following manner. The analyte is first deposited (preconcentrated) electrochemically by reducing the dissolved ion in solution to immobilized metal species at a mercury electrode surface. The metal is deposited in the form of an amalgam (with Hg) at an applied potential (voltage) which is negative of the standard oxidation potential for the metal/ion redox couple. After deposition, the preconcentrated metal species is then "stripped" from the mercury electrode by applying a positive potential sweep, which causes anodic oxidation of the analyte metal species to dissolved ion. The current associated with this reoxidation is measured. The peak current is proportional to the original concentration of dissolved analyte species over a wide range of concentrations.

3.3 *colorimetry*—an analytical technique that is similar to

[1] This guide is under the jurisdiction of ASTM Committee E-6 on Performance of Buildings and is the direct responsibility of Subcommittee E06.21 on Lead Paint Abatement.

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[2] *Annual Book of ASTM Standards*, Vol 04.07.

[3] Available from U.S. EPA, Office of Research and Development, Research Triangle Park, NC.

[4] Available from U.S. EPA, Office of Pollution Prevention and Toxic Substances, Washington, DC.

spectrophotometry (see 3.5), except that ultraviolet-visible light of a single, narrow wavelength range is passed through a sample cell containing dissolved analyte, and the absorption measured.

3.4 *reflectance*—a measurement technique (subset of spectrophotometry; see 3.5) in which light is reflected off of a reflecting surface and measured by a detector. The amount of reflected light may be a function of analyte concentration.

3.5 *spectrophotometry*—an analytical technique in which a spectrum of analyte species is obtained and used to determine the analyte concentration in the following manner. Light is directed onto or through analyte species, and the absorption of this light across a range of wavelengths is measured by a detector. The amount of absorbed light is a function of the concentration of analyte species.

4. Significance and Use

4.1 This guide is intended for use in evaluating the performance of field-portable electroanalytical or spectrophotometric devices for lead determination, or both.

4.2 Desired performance criteria for field-based extraction procedures are provided.

4.3 Performance parameters of concern may be determined using protocols that are referenced in this guide.

4.4 Reference materials to be used in assessing the performance of field-portable lead analyzers are listed.

4.5 Exhaustive details regarding quality assurance issues are outside the scope of this guide. Applicable quality assurance aspects are dealt with extensively in references that are cited in this guide.

5. Performance Evaluation Materials

5.1 *Standard Reference Materials*—These consist of NIST Standard Reference Materials (SRMs) and are also known as Primary Reference Materials:

5.1.1 *Paint*—NIST 1579 (lead-based paint), other NIST paint SRMs, for example, NIST SRM 2582, and new SRMs currently under development.

5.1.2 *Dust*—NIST 1648 (urban particulate matter), other NIST dust SRMs, and new materials under development.

5.1.3 *Soil*—NIST 2704 (river sediment) and NIST soil standards: SRMs 2709, 2710, and 2711.

5.1.4 *Airborne Particulate*—No NIST SRMs are available for airborne particulate collected on filters. In lieu of this, use NIST urban particulate SRM 1648 (see 5.1.2).

5.2 *Real-World Materials:*

5.2.1 *Paint*, collected using Practice E 1729. To obtain reference values, determine lead concentration using Test Method E 1613 and Practice E 1645.

5.2.2 *Dust Wipes*, collected using Practice E 1728. To obtain reference values, determine lead concentration using Test Method E 1613 and Practice E 1644.

5.2.3 *Vacuumed Dust*, collected using Practice D 5438. To obtain reference values, determine lead concentration using Test Method E 1613 and Practice E 1726.

5.2.4 *Soil*, collected using Practice E 1727. To obtain reference values, determine lead concentration using Test Method E 1613 and Practice E 1726.

5.2.5 *Airborne Particulate*, collected using Practice E 1553. To obtain reference values, determine lead concentration using Test Method E 1613 and Practice E 1741.

5.3 *Secondary Reference Materials*—Examples include samples from the Environmental Lead Proficiency Analytical Testing (ELPAT) program (paints, dusts spiked on wipes, and soils) and the Proficiency Analytical Testing (PAT) program (air filters).[4] Other examples include secondary reference materials (for example, bag house dust, sludge, and solid waste).[5]

5.3.1 *Paint*—Examples include ELPAT paint samples.

5.3.2 *Dust*—Examples include ELPAT wipe samples spiked with lead-containing dusts.

5.3.3 *Soil*—Examples include ELPAT soil samples.

5.3.4 *Air Filters*—Examples include PAT air filter samples.

6. Performance Criteria

6.1 *Extraction Procedures*—The extraction procedure chosen shall have a demonstrated recovery of at least 80 % for the matrix of concern, and shall be compatible with the lead analysis technique used (EPA 600/R-93/200). (Reference extraction and analytical techniques include those ASTM standards listed in 2.1.)

6.2 *Field-Portable Analysis:*

6.2.1 *Accuracy*—Overall measurement accuracy of the field-portable analytical technique following field-based extraction: within 25 % of the values obtained by the applicable ASTM extraction procedure (see 2.1) and Test Method E 1613.

6.2.2 *Precision*—For field-based extraction followed by field-portable analysis, total uncertainties for standard reference materials: 15 % relative standard deviation (RSD) (EPA 747-R-92-001); for real-world materials: 25 % RSD (EPA 747-R-92-001); for secondary reference materials: 20 % RSD.

6.2.3 *Working Range*—Working concentration range for the overall method shall extend from 0.1 times the applicable action level to 10 times the applicable action level (NIOSH SOP 018)[7] for the sample matrix of concern.

6.3 *Sample Size*—Follow applicable ASTM sample collection and sample preparation practices listed in 2.1.

7. Quality Assurance (QA) and Quality Control (QC)

7.1 *Field and Laboratory QA/QC*—Follow QA/QC procedures delineated in the applicable ASTM sample preparation practices for the pertinent sample matrix (2.1) and in Test Method E 1613.

7.2 *QA System*—Follow the requirements delineated in Practice E 1583.

8. Keywords

8.1 electroanalysis; extraction; lead; portable analysis; spectrophotometry

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[4] Available from the American Industrial Hygiene Association, Fairfax, VA.

[5] Available from Pioneer Scientific and Resource Technology Corp., Laramie, WY.

[7] *NIOSH Quality Assurance Manual*, available from the National Institute for Occupational Safety and Health, Division of Physical Sciences and Engineering, Cincinnati, OH (1993).

Appendix G: Standard Practice for Collection of Airborne Particulate Lead during Abatement and Construction Activities (ASTM Standard E 1553-93)

Designation: E 1553 - 93

Standard Practice for Collection of Airborne Particulate Lead During Abatement and Construction Activities[1]

This standard is issued under the fixed designation E 1553; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the collection of airborne particulate lead during abatement and construction activities. The practice is intended for use in protecting workers from exposures to high concentrations of airborne particulate lead. This practice is not intended for the measurement of ambient lead concentrations in air.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1356 Terminology Relating to Atmospheric Sampling and Analysis[2]

D 1605 Practice for Sampling Atmospheres for Analysis of Gases and Vapors[3]

D 3195 Practice for Rotameter Calibration[2]

2.2 *Federal Regulations:*

29 CFR Part 1910.1025, Lead, Occupational Safety and Health Standards[4]

Code of Federal Regulations, Title 40, Chapter I—Environmental Protection Agency, Appendix G (EPA Method for Ambient Lead in Air)[4]

3. Terminology

3.1 *Definitions*—For definitions of terms relating to atmospheric sampling and analysis that are not given here, refer to Terminology D 1356.

3.1.1 *air sampling pump*—a portable, battery-powered air pump that may be attached to a belt on a worker or to a stationary object. The pump is used to draw air through a filter holder that is placed within the personal breathing zone of a worker. Alternatively, the pump may be attached to a stationary object in order that it may be used for area sampling.

3.1.2 *area samples*—air samples that are collected at various stationary sites, but not for a person; area samples are therefore to be distinguished from personal air samples.

3.1.3 *batch*—a group of samples ($n > 2$) that are obtained in a similar environment (for example, a set of area or personal samples) and are processed together using the same reagents and equipment.

3.1.4 *field blank*—a sample that is handled in exactly the same way that field samples are handled, except that no air is drawn through it.

3.1.5 *filter holder*—a plastic holder that supports the filter medium upon which airborne particulate matter is collected.

3.1.6 *personal air samples*—air samples that are collected within the personal breathing zone (PBZ) of a person.

3.1.7 *personal breathing zone (PBZ)*—an area within approximately 6 in. of a person's face.

3.1.8 *sampling device*—a filter holder and air sampling pump assembly used to collect airborne particulate lead on a filter. The filter holder houses a cellulose ester membrane filter, through which air is drawn by using an air sampling pump; the filter holder is connected to the pump by tubing.

4. Summary of Practice

4.1 Particulate matter containing lead is collected from air on a cellulose ester membrane filter. The sample is then to be prepared for shipment (and ultimate digestion and laboratory analysis).

5. Significance and Use

5.1 Human exposure to lead-containing particulates has been demonstrated to cause a variety of physiological disorders, for example, neurological, hematological, etc. This practice is to be used for the collection of airborne lead during various construction and renovation activities associated with lead paint abatement and removal in and around buildings and related structures. It may also be used with other work practices such as battery recycling, smelting, law enforcement (firing ranges), etc. Determination of lead concentration in air is used to assess the potential of human exposure to airborne particulate lead.

5.2 The practice involves the use of personal sampling pumps to collect airborne particulate lead and is intended for use by qualified industrial hygienists.[5]

5.3 The practice can also be used by regulatory agencies such as OSHA for monitoring airborne lead levels at worksites and to ensure that lead concentrations in workplace air do not exceed the permissible exposure limit (PEL). See 29 CFR 1910.1025.

5.4 This practice does not involve the use of high-volume

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[1] This practice is under the jurisdiction of ASTM Committee E-6 on Performance of Buildings and is the direct responsibility of Subcommittee E06.23 on Abatement of Lead Hazards in Buildings.

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[2] *Annual Book of ASTM Standards*, Vol 11.03.

[3] *Discontinued—See 1991 Annual Book of ASTM Standards*, Vol 11.03.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[5] Eller, P. M., Ed., *NIOSH Manual of Analytical Methods*, 3rd ed., Methods 7082, 7105, and 7300, National Institute for Occupational Safety & Health, Cincinnati, OH, 1984, Supplement 1990.

samplers that are used to measure ambient airborne lead concentrations. See EPA Method for Ambient Lead in Air.

6. Apparatus

6.1 *Air Sampling Equipment*—The sampling unit for the collection of personal air samples has the following components:

6.1.1 *Cellulose Ester Membrane Filters*, 0.8 μm pore size, 37 mm diameter.

6.1.2 *Filter Holder* for 37 mm diameter filters, either two- or three-piece.

6.1.3 *Portable, Battery-powered Air Sampling Pump*, capable of 0 to 5 L/min flow rate and of sufficient capacity to maintain a face velocity of 2.6 cm/sec. The pump must be calibrated with a representative filter unit so that the volume of air sampled can be measured to an accuracy of ±5 %.

6.1.4 *Assorted Clips, Tubing, Spring Connectors, and Belt* for connecting the air sampling apparatus to a person or object.

6.2 *Ancillary Supplies:*

6.2.1 *Laboratory Thermometer*, accurate to the nearest 0.1°C.

6.2.2 *Manometer*, accurate to nearest ±4 mm Hg.

6.2.3 *Stopwatch*, accurate to nearest 0.1 sec.

6.2.4 *Powderless Plastic Gloves.*

6.2.5 *Tweezers.*

7. Sampling

7.1 Assemble the filter in a two- or three-piece filter holder, with the filter supported on a stainless steel screen or cellulose backup pad. Close the filter holder cartridge firmly to prevent sample leakage around the filter. Seal the filter holder with plastic tape or a shrinkable cellulose band, and label the filter holder. To prevent contamination of the filter and filter holder, wear powderless gloves and handle the filter with tweezers during assembly.

7.2 Using a soap bubble meter or an equivalent calibration device (see Terminology D 1356, Practices D 1605 and D 3195, and footnote 6), set the flow rate (in L/min) of each sampling pump with a filter holder (plus filter) in the line, per manufacturer's instructions. Air sampling pumps must be calibrated each day prior to and following use. Calibration records should be kept in either a laboratory notebook or a data sampling sheet for each pump that is used.

7.3 Remove the filter holder plugs and attach the filter holder to the air sampling pump with a piece of flexible tubing, length ca. 2.5 ft. For personal air monitoring, clip the filter holder to the person's clothing so that the filter cassette is placed within the PBZ. For area samples, attach the filter holder, which is connected to an air sampling pump, in the desired location. For both personal and area sampling, ensure that the inlet end of the filter cassette is pointed downwards. Air that is being drawn through the filter should not be passed through any hose or tubing before entering the filter holder.

7.4 Obtain an air sample at a known flow rate between 1 and 4 L/min for up to 8 h for time-weighted averaged (TWA) measurements, until the recommended sample volume is reached.

7.5 Avoid excessive overloading of the filter; this problem can be identified by a >10 % drop in the measured face velocity. A subjective indicator of possible overloading is excessive darkening of the filter. If overloading of samples becomes evident, reduce the sampling time to prevent filter overloading.

7.6 Prepare field blanks at about the same time that sampling has been initiated; these should represent 5 % of the total number of samples or at least one per batch minimum. Field blanks shall be handled in the same fashion as the personal or area air samples, or both, but no air shall be drawn through the filters.

7.7 After sampling area or personal samples, or both, for a prescribed period of time, disconnect the filter holder from the air sampling pump. Cap the inlet and outlet of the cassette with plugs, and label the sample.

7.8 Record pertinent sampling data for each sample, that is, times of beginning and end of sampling, initial and final air temperatures, and atmospheric pressure. Record the type of personal sampling pump and location of sampling device during sampling. Record the initial and final flow rates (L/min) for each air sampling pump.

7.9 Once collected, samples shall be placed in airtight containers, such as zip-lock plastic bags.

7.10 Samples are to be transported so that the filter holders and filters containing airborne particulate are neither disturbed nor contaminated. Samples are to be transported to the laboratory for sample preparation and analysis, and filters are not to be removed from the filter holders before or during transport.

7.11 For general information on sampling, refer to Practices D 1356 and D 1605.

8. Report

8.1 Parameters such as flow rate, number of samples, number of blanks, air sampling pump used, pump settings, calibration data (before and after pump use), length of time each sample was pumped, etc. are to be reported. Also, report the date and site where samples are obtained. Other information that should be recorded includes weather conditions, number of workers, type of work practice, and any other information deemed important. All of this information should be recorded in a laboratory notebook or data sampling form, or both.

9. Precision and Bias

9.1 The relative error in calibration of personal sampling pumps is ±5 %.[6]

9.2 No significant bias has been identified.[3]

10. Keywords

10.1 airborne particulate lead; collection; sampling

[6] Lippmann, M. *Air Sampling Instruments*, 7th ed.; American Conference of Government Industrial Hygienists: Cincinnati, OH, 1989, Chapter F.