# Chapter 5
# Health Effects and Control of Toxic Lead in the Environment

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**Abstract** Lead is a heavy metal that occurs naturally in the Earth's crust. Lead does not break down in the environment; if left undisturbed, lead is virtually immobile. However, once mined and transformed into man-made products dispersed throughout the environment, lead becomes highly toxic to humans. Lead is ubiquitous in older American homes in house paint and is common in certain industrial workplaces, due to its widespread use over the course of the past century.

The health effects of lead poisoning can be quite serious, and there are numerous regulations regarding its use. The Consumer Product Safety Commission bans the use of lead-based paint in residences. The Occupational Safety and Health Administration sets limits on permissible exposure to lead in the workplace. However, because lead-based paint inhibits the rusting and corrosion of iron and steel, lead continues to be used on bridges, railways, ships, lighthouses, and other steel structures. This is the case even though substitute lead-free coatings are available.

Lead is most commonly absorbed into the body by inhalation, in the form of lead-contaminated dust or mist, often generated from old lead-based paint that has begun to chip. A significant portion of inhaled or ingested lead is absorbed into the bloodstream. Once in the bloodstream, lead circulates through the body and is stored in various organs and body tissues. As exposure continues, the amount stored will increase and accumulate in the body, where it can slowly cause irreversible damage, first to individual cells, then to organs and whole body systems.

Lead is toxic to both male and female reproductive systems. Lead can lead to miscarriage and stillbirth in women exposed to lead. Children born to parents who were exposed to excess lead levels are more likely to have birth defects, mental retardation, or behavioral disorders and are more likely to die during the first year of childhood. Lead is much more harmful to children than adults because it can affect

children's brains and nervous systems, which are still developing. Children are more vulnerable to permanent damage; for example, learning disabilities, behavioral abnormalities, attention deficit problems, and insomnia.

Children are also at higher risk because they are more likely to unknowingly inhale or ingest lead. Exposure to lead in house dust tends to be highest for young children, due to their frequent and extensive contact with floors, carpets, window areas, and other surfaces where dust gathers, as well as their frequent hand-to-mouth activity. It is common for young children to put everything, including hands, pacifiers, toys, and other small objects, into their mouths.

Workers involved in iron work, demolition work, painting, lead-based paint abatement, plumbing, heating and air conditioning, and carpentry are also potentially at risk for high lead exposure.

There have been significant efforts over the past few decades to reduce lead exposure in the USA, but lead poisoning is still an important public health issue. To address potential lead poisoning, a risk evaluation of a building or home will determine the risk and extent of the lead hazard present. Once a lead risk is confirmed, the building should undergo abatement, the process of eliminating or mitigating the lead hazard. There are several approaches to abatement that can be taken.

This chapter will discuss the health effects of lead on children, women, workers, and their protection. It will then detail the types of abatement and how they can be implemented. The risk evaluation and the US federal and New York State rules and regulations on lead will also be discussed.

**Keywords** Heavy metal • Lead • Lead poisoning • Lead-based paint • Lead exposure • Lead hazard • Lead-contaminated dust • Occupational lead exposure criteria • Blood lead level (BLL) • Permissible exposure limit (PEL) • Health effect • Worker • Children • Infant • Women • Male infertility • Paint replacement • Enclosure installation • Encapsulation • Paint removal • Abatement procedures • Risk management • Hazard screen • Hazard control • Rules • Regulations • US EPA • New York State

## Acronym

| | |
|---|---|
| ABLES | New Jersey Adult Blood Lead Epidemiology and Surveillance System |
| ACCLPP | Advisory Committee on Childhood Lead Poisoning Prevention |
| ACGIH | American Conference of Government Industrial Hygienists |
| ASTM | American Society for Testing and Materials |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BLL | Blood lead level |
| CDCP | Centers for Disease Control and Prevention |
| CPSC | Consumer Product Safety Commission |
| FDA | Food and Drug Administration |
| HEPA | High-efficiency particulate air |

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|---|---|
| HUD | US Department of Housing and Urban Development |
| LBP | Lead-based paint |
| MCLG | Maximum contaminant level goal |
| MSDS | Material safety data sheet |
| NAAQS | National Ambient Air Quality Standard |
| NHANES | National Health and Nutrition Examination Survey |
| NIOSH | National Institute for Occupational Safety and Health |
| NLLAP | National Lead Laboratory Accreditation Program |
| NTP | National Toxicology Program |
| NYCRR | New York Codes, Rules, and Regulations |
| NYS | New York State |
| NYSDOH | New York State Department of Health |
| OSHA | Occupational Safety and Health Administration |
| PEL | Permissible exposure limit |
| PPE | Personal protection equipment |
| PPM | Parts per million |
| REL | Recommended exposure limit |
| TLV | Threshold limit value |
| TSCA | Toxic Substances Control Act |
| TWA | Time-weighted average |
| US EPA | US Environmental Protection Agency |
| μg/dL | Microgram per deciliter |
| μg/g | Microgram per gram |
| μg/L | Microgram per liter |
| $\mu g/m^3$ | Microgram per cubic meter |

## 1 Introduction

Lead is a malleable, blue-gray, heavy metal that occurs naturally in the Earth's crust, with trace amounts found in soil and plants. Since lead is a natural element, it does not break down in the environment. If left undisturbed, lead is virtually immobile. However, once mined and transformed into man-made products that are dispersed throughout the environment, lead becomes highly toxic.

Lead is used to produce a variety of industrial and consumer products and is frequently used in construction and electrical conduits. In plumbing, soft solder, which is used chiefly for soldering, is an alloy of lead and tin. Lead is ubiquitous in older American homes painted with lead-based paint. Lead exposures in industrial workplaces or construction sites are common because of the widespread use, during the past century, of lead compounds in paints, gasoline, and various industrial materials.

Soft solder has been banned for many uses in the USA. In addition, the Consumer Product Safety Commission bans the use of lead-based paint in residences. Because lead-based paint inhibits the rusting and corrosion of iron and steel, however, lead continues to be used on bridges, railways, ships, lighthouses,

and other steel structures, although substitute coatings are available. Today lead is still found in:

1. House paint made before 1978
2. Toys and furniture made before 1976
3. Painted toys and decorations
4. Lead bullets, fishing sinkers, and curtain weights
5. Plumbing, pipes, and faucets
6. Soil contaminated by decades of car exhaust and lead-based gasoline spills
7. Dust from years of house paint scraping
8. Hobbies involving soldering, stained glass
9. Children's paint sets and art supplies
10. Pewter pitchers and dinnerware
11. Storage batteries

For centuries, exposure to high concentrations of lead has been known to pose health hazards. Lead's toxicity was recognized as early as 2000 BC [1].

Lead is most commonly absorbed into the body by inhalation, in the form of lead-contaminated dust or mist. Once the dust or mist is inhaled, the lungs and upper respiratory tract absorb it into the body. Lead can also be absorbed through the digestive system if it enters the mouth and is ingested.

A significant portion of inhaled or ingested lead gets absorbed into the bloodstream. Once in the bloodstream, lead circulates through the body and is stored in various organs and body tissues. As exposure continues, and if the body absorbs more lead than it excretes, the amount stored will increase and accumulate in the body. The lead stored in the tissue can slowly cause irreversible damage, first to individual cells, then to organs and whole body systems.

There are many possible symptoms of lead poisoning. Some of the common symptoms include:

1. Loss of appetite
2. Constipation
3. Nausea
4. Excessive tiredness
5. Headaches
6. Fine tremors
7. Severe abdominal pain
8. Metallic taste in the mouth
9. Weakness
10. Nervous irritability
11. Hyperactivity
12. Muscle and joint pain or soreness
13. Anxiety
14. Pallor
15. Insomnia
16. Numbness
17. Dizziness

Lead is toxic to both male and female reproductive systems. Lead can alter the structure of sperm cells; and there is evidence of increased miscarriage and stillbirth in women exposed to lead or whose partners have been exposed to lead. Children born to parents who were exposed to excess lead levels are more likely to have birth defects, mental retardation, or behavioral disorders and are more likely to die during the first year of childhood.

Because of lead's ubiquitous presence in industrial societies, there are many sources and pathways of lead exposure in children. These include lead-based paint in industrial, commercial, and residential buildings and equipment, lead-based paint in art, dust and soil contaminated by lead, presence of lead in drinking water distribution systems, and current use of lead in the manufacture of some products like toys.

It is common for young children to put everything, including hands, pacifiers, toys, and other small objects, into their mouths. Anything which contains lead, from small dust particles to large paint chips, can cause harm if swallowed. Exposure to lead in house dust tends to be highest for young children, due to their frequent and extensive contact with floors, carpets, window areas, and other surfaces where dust gathers, as well as their frequent hand-to-mouth activity.

Lead poisoning commonly contributes to problems which may become permanent in young children. Learning disabilities, behavior abnormalities, attention deficit problems, and insomnia are common symptoms. Lead is much more harmful to children than adults because it can affect children's brains and nervous systems, which are still developing.

Children less than 6 years of age are of special concern because their developing brains and bodies can easily be damaged by lead and because they are more likely to put the lead-contaminated dust, loose paints, etc., into their mouths.

Unborn children are the most vulnerable. Possible complications in behavior or attention problems include:

1. Failure at school
2. Hearing problems
3. Kidney damage
4. Reduced IQ
5. Slowed body growth

Workers potentially at risk for lead exposure include those involved in iron work, demolition work, painting, lead-based paint abatement, plumbing, heating and air conditioning, and carpentry, among others.

Lead-based paint is paint containing lead pigment. Chrome yellow is a yellow pigment containing lead chromate $PbCrO_4$. Lead white is a white pigment containing lead carbonate $PbCO_3$. Lead pigment is added to paint liquid for speeding up the drying process, increasing paint's durability, resisting corrosion, and maintaining an attractive appearance. Lead-based paint is one of the main environmental and health hazards.

Once discovered, lead hazards must be eliminated and/or reduced, a process called abatement. There are four general approaches to abatement depending on the

existence, nature, severity, and location of lead-based hazards: replacement, enclosure, encapsulation, and paint removal.

1. Replacement is removal of lead-based painted components and replacing them with new "lead-free" components.
2. Encapsulation is the coating of a lead-based painted surface with rigid materials that rely on adhesion to that surface instead of being mechanically fastened.
3. Enclosure involves covering the lead-based paint with a solid, dust-tight barrier so that it is completely enclosed.
4. Paint removal is removal of lead-based paint from building components, leaving the subsurface intact.

Once abatement is completed, the property must be cleared—that is, it must be inspected to ensure that it clears acceptable standards for lead hazards.

There are numerous regulations and laws relevant to lead poisoning and abatement. Some of the federal agencies that oversee or regulate lead in the USA include the US Environmental Protection Agency (US EPA), Centers for Disease Control and Prevention (CDCP), and the National Institute for Occupational Safety and Health (NIOSH), which is part of the CDC. The Occupational Safety and Health Administration (OSHA) sets guidance on lead exposure in workplace settings; and the Department of Housing and Urban Development (HUD) does so with regard to housing. There are other rules and regulations from state and local authorities.

A risk evaluation is usually performed to identify the lead risk and to determine the best approach for abatement. There are four ways to perform risk evaluation: risk assessment, lead hazard screen, lead-based paint inspection, and combination inspection/risk assessment. Risk assessment is on-site investigations to determine the existence, nature, severity, and location of lead-based paint hazards; lead hazard screen identifies lead-based paint hazard and other potential lead hazards. Lead-based paint inspection involves conducting a visual assessment, analyzing dust and soil samples, and interviewing property owners or residents.

The issues to be addressed in the following sections include:

1. Health effects on children, women, and lead-based paint workers
2. Abatement approaches
3. Risk evaluation
4. Federal rules and lead standards

## 2 Lead Exposure and Health Effects

The toxic health effects of lead in both children and adults are well documented. Lead exposure in adults can damage the central nervous system, cardiovascular system, reproductive system, hematological system, and the kidneys. Lead exposure in adults can also harm the development of their children. Lead has been shown to be an animal carcinogen as well, and toxic lead compounds are listed under

various categories by the International Agency for Research on Cancer (IARC) (www.cancer.org).

The most vulnerable groups are children, nursing and pregnant women, and workers who work with lead-based paint or other lead-based materials. Lead is much more harmful to children than adults because it can affect children's brains and nervous systems, which are not yet fully developed. The younger the child, the more harmful lead can be.

The well-known danger of lead poisoning prompted government action in 1978, when the Occupational Safety and Health Administration (OSHA) promulgated a lead standard to protect workers in general industry.

Because of these national efforts to reduce environmental lead exposures, general population lead exposures in the USA have dropped significantly in the past two decades. Lead exposures in the workplace, however, continue to be a significant public health problem. One complicating factor is the nature of the symptoms of lead poisoning; lead poisoning often goes undetected since many of the symptoms, such as stomach pain, headaches, anxiety, irritability, and poor appetite, are nonspecific and may not be immediately recognized as symptoms of lead poisoning.

Research studies on lead toxicity in humans indicate that current OSHA standards should prevent the most severe symptoms of lead poisoning, but these standards do not fully protect workers and their developing children from all of the adverse effects of lead.

## *2.1 Occupational Lead Exposure Criteria*

Human lead exposure occurs when dust and fumes are inhaled or when lead is ingested via lead-contaminated hands, food, water, cigarettes, and clothing. Once exposure occurs, lead entering the respiratory and digestive systems is released into the bloodstream and distributed throughout the body. More than 90 % of the total body burden of lead is accumulated in the bones, where it can remain for decades. In addition, secondary exposure may occur; lead that has accumulated in bones may be subsequently released into the blood and reexpose organ systems long after the original environmental exposure. In pregnant women, this process can also expose the fetus to lead.

There are several biological indices of lead exposure. Lead concentrations in the blood, urine, teeth, and hair can be used as indicators to measure the level of lead exposure. At present, the best available method for monitoring biological exposure to lead is measurement of the blood lead level (BLL), usually measured in micrograms/deciliter (μg/dL) of blood.

Under the OSHA general industry lead standard (29 CFR 1910.1025), the permissible exposure limit (PEL) for personal exposure to airborne inorganic lead was set in 1978, at a maximum BLL of 50 $\mu g/m^3$ (micrograms per cubic meter of air). Specifically, the OSHA set a PEL of 50 $\mu g/m^3$ averaged over an 8-h period

(as an 8-h time-weighted average or TWA), when respirators are used, and a PEL of 30 μg/m$^3$ when respirators are not used. The 1970s saw the elimination or restriction of the use of leaded gasoline and lead-based paint in the USA. Maintaining the concentration of airborne particles of lead in the work environment below the PEL is a preventive measure intended to protect workers from excessive exposure. Much progress has been made in reducing general lead exposures; more than 90 % of adults now have a BLL < 10 μg/dL, and more than 98 % have a BLL < 15 μg/dL. However, exposures in the workplace continue to be a significant public health problem. Even with the federal regulations, thousands of adults with BLLs of at least 25 μg/dL are reported each year to NIOSH by states participating in a NIOSH surveillance program.

In the 1978 general industry standard, OSHA advised that men or women planning to have children should limit their exposure to maintain a BLL less than 30 μg/dL.

Research studies on lead toxicity in humans indicate that while current OSHA standards should prevent the most severe symptoms of lead poisoning, they do not protect workers and their children from all of the adverse effects of lead. Even lower BLLs, within the permissible limit, can cause damage. In recognition of this problem, standards and public health goals, set up by various agencies, have established lower exposure limits for workers exposed to lead, to offer increased protection for those workers and their children.

## *2.2 General Health Effects of Lead Exposure on People of All Ages*

The health effects of lead have been previously extensively documented by the federal public health agencies: Agency for Toxic Substances and Disease Registry (ATSDR), Centers for Disease Control and Prevention (CDCP), and National Institute for Occupational Safety and Health (NIOSH) [2–4].

Excessive exposure to lead can lead to several types of health effects, such as neurotoxic effects, hematological and renal effects, cardiovascular effects, and reproductive problems. These are described in greater detail below.

### 2.2.1 Neurotoxic Effects

One of the major targets of lead toxicity is the nervous system, including the central and peripheral nervous systems. Lead damages the blood-brain barrier and, subsequently, contaminated blood can harm brain tissues. Severe exposures resulting in BLLs > 80 μg/dL may cause coma, encephalopathy, or even death.

Because of the improved control of occupational lead exposures in recent decades, such occurrences of extreme lead toxicity are rare today in the USA.

Occupational lead exposures allowable under the current OSHA lead standards will not produce these obvious neurologic clinical symptoms. However, lead exposure levels permissible under the OSHA standards may still be harmful to the central nervous system. Workers with BLLs of 40–50 μg/dL may experience fatigue, irritability, insomnia, headaches, and subtle evidence of mental and intellectual decline [5, 6]. BLLs as low as 30–40 μg/dL decrease motor nerve conduction velocity in workers, although these lead exposure levels are not associated with clinical symptoms [7]. These subclinical symptoms represent early stages of neurologic damage to the central and peripheral nervous system.

### 2.2.2 Hematologic and Renal Effects

Anemia, a blood iron deficiency, is one of the most characteristic symptoms of high and prolonged human exposures to lead, associated with BLLs $> 80$ μg/dL. For children, a significant association was found for mild and severe anemia, even at the BLL range of 10–20 μg/dL. The anemia results from the damaging effects of lead on the formation and functioning of red blood cells.

Chronic high exposure to lead, above the OSHA permissible exposure limits (PEL) of 50 $\mu g/m^3$, may cause chronic nephropathy and, in extreme cases, kidney failure. There is substantially less evidence of kidney disease at lower exposures to lead [8].

### 2.2.3 Reproductive and Developmental Effects

Historical studies indicate that high exposures to lead can produce stillbirths and miscarriages [9]. Several studies conducted in the USA and abroad have indicated that exposures to lower concentrations of lead, with BLLs at or below 15 μg/dL, may result in adverse pregnancy outcomes, such as shortened time of gestation and decreased fetal mental development and growth [10, 11].

The developing nervous system of the fetus is particularly vulnerable to lead toxicity. Neurological toxicity is observed in children of exposed female workers, a result of the ability of lead to cross the placental barrier and to cause neurological impairment in the fetus [12].

BLLs of 60 μg/dL or higher may be associated with male infertility [13]. Studies in male workers also indicate that exposures to lead resulting in BLLs as low as 40 μg/dL may cause decreased sperm count and abnormal sperm morphology [14, 15].

Several reports indicate that decreased sperm quality and hormonal changes can occur among male workers exposed to lead with BLLs of 30–40 μg/dL [16, 17].

### 2.2.4 Cardiovascular Effects

Chronic high exposures to lead that occurred earlier in the last century were associated with an increased incidence of hypertension and cardiovascular disease [18]. Today these severe effects of lead exposure are rarely observed in the USA [19]. Studies conducted in the general population, where lead exposures are much lower, have also indicated that increased BLLs are associated with small increases in blood pressure. This relationship appears to extend to BLLs below 10 μg/dL [20–23].

### 2.2.5 Carcinogenic Effects

Results from two studies indicate that lead may increase the risk of cancer among workers exposed to high levels of lead [24, 25].

## *2.3 Health Effects of Lead Exposure on Children*

While people of all ages can suffer from excessive lead exposures, the groups most at risk are fetuses, infants, and children under 6 years of age, because they are more vulnerable to the effects of lead poisoning and because they are more likely to unknowingly expose themselves to lead.

Because children's brains, nervous systems, and other body systems are still developing, they sustain the greatest impact of lead exposure. The first 3 years of life are characterized by major growth and developmental events in the nervous system, so young children have increased susceptibility to the neurodevelopmental effects of lead [26]. Once absorbed, some lead goes into the blood and can be eliminated more quickly, but most of the lead is stored in bones, where it can stay many years.

Lead poisoning commonly contributes to a variety of problems that may ultimately become permanent in young children. Lead can have neurotoxic effects even at low levels, causing reductions in attention span, reading and learning disabilities, hyperactivity, insomnia, and behavioral problems and abnormalities [27]. The National Toxicology Program (NTP) has concluded that childhood lead exposure is associated with reduced cognitive function [28]. Children with higher blood lead levels generally have lower scores on IQ tests [29–35] and reduced academic achievement [28]. In addition to the effects on IQ and school performance, research on the effects of lead has increasingly been addressing the effects of lead on behavior.

Lead poisoning affects children across all socioeconomic strata and in all regions of the country. However, because lead-based paint hazards are most severe in older, dilapidated housing, the poor in inner cities are disproportionately affected.

Despite steady and impressive progress since the 1970s in reducing blood lead levels (BLL) among the US population, childhood lead poisoning remains a major, but preventable, environmental health problem in the USA. Children continue to be exposed to lead due to the widespread distribution of lead in the environment.

### 2.3.1 Lead in Surface Dust

In the USA, the major current source of early childhood lead exposure is lead-contaminated house dust ingested by normal hand-to-mouth and toy-to-mouth activity. The major contributor to lead in house dust is deteriorated or disrupted lead-based paint [36–40] most typically found in older houses. Leaded dust is generated as lead-based paint deteriorates over time, damaged by moisture, abraded on friction and impact surfaces, or disturbed in the course of renovation, repair, or abatement projects. Deteriorating paint can also chip and fall to floors or window sills, creating lead-based paint chips that children may ingest. The likelihood, extent, and concentration of lead-based paint increase with the age of the building. Because the greatest risk of paint deterioration is in dwellings built before 1950, older housing generally commands a higher priority for lead hazard controls [41].

### 2.3.2 Lead in Soil

Children can be exposed to lead from direct contact with lead-contaminated soil or soil tracked in from outside the home. The high levels of lead in soil typically come from deteriorating exterior lead-based paint around the foundation of a house. Other known sources of lead in soil include historical airborne emissions of leaded gasoline and emissions from industrial sources such as smelters [26, 42–45].

### 2.3.3 Other Causes of Lead Poisoning

Children can also be exposed to lead in drinking water or by inhaling lead in ambient air. Contamination of drinking water can occur from corrosion of lead pipes and other elements of water distribution systems. Exposure via drinking water may be particularly high among very young children who consume baby formula prepared with water that is contaminated by leaching lead pipes [40, 46, 47].

Other sources and pathways of lead poisoning in children can include point sources, ceramics, toys, children's jewelry, lead brought home from a parent's workplace, imported candy and its candy wrappers, home and folk remedies, cosmetics, and hobby supplies [48, 49]. These sources may account for a small amount of children's exposure; for most children, paint, dust, and soil are the primary sources of lead poisoning.

Mothers who are exposed to lead can also transfer lead to the fetus during pregnancy and to the child while breast feeding [48, 49].

While infants and very young children are at greatest risk, lead is toxic to children older than 5 years as well; they are also susceptible to the neurodevelopmental effects of lead.

In October 1991, CDCP formally revised its statement on Preventing Lead Poisoning in Young Children [2] reducing its "level of concern" for childhood lead poisoning from the previous threshold of 25 μg/dL to 10 μg/dL.

Until recently, CDCP had defined this blood lead level of 10 micrograms per deciliter (μg/dL) as "elevated"; this definition was used to identify children for blood lead case management [50, 51]. CDCP now specifically notes that "no level of lead in a child's blood can be specified as safe," and the NTP has concluded that there is sufficient evidence of adverse health effects in children at blood lead levels less than 5 μg/dL [28, 36].

CDCP recommends that sources of lead in children's environments be controlled or eliminated before children come into contact with them and are poisoned, i.e., "primary prevention" [52, 53].

## *2.4 Health Effects of Lead Exposure on Women and Infants*

Lead exposure remains a concern for pregnant and lactating women. There is increasing awareness that unintended exposures to environmental contaminants such as lead adversely affect maternal and infant health, including the ability to become pregnant, maintain a healthy pregnancy, and have a healthy baby.

However, guidance for clinicians and prenatal health-care providers regarding screening and managing pregnant and lactating women exposed to lead has not kept pace with the scientific evidence. There are currently no national recommendations by any medical, obstetric, family practice, or pediatric nursing professional association that covers lead risk assessment and management during pregnancy and lactation.

The CDCP has not identified an allowable exposure level, level of concern, or any other bright line intended to connote a safe or unsafe level of lead exposure for either mother or fetus. In other words, there is no apparent threshold below which adverse effects of lead do not occur. Instead, CDCP is applying public health principles of prevention, i.e., recommending follow-up blood lead testing and interventions when prudent. These guidelines recommend follow-up activities and interventions beginning at BLLs of $\geq$5 μg/dL in pregnant women.

There is evidence that a significant number of pregnant women and presumably their infants are being exposed to lead in the USA today. Lead exposure remains a public health problem for subpopulations of women of childbearing age and for the developing fetus and nursing infant as prenatal lead exposure has known influences on both maternal health and infant birth and neurodevelopmental outcomes [54].

Since bone lead stores persist for decades, women and their infants may be at risk for continued exposure long after initial exposure to external environmental sources has been terminated.

High levels of lead exposure can result in delirium, seizures, stupor, coma, or even death. Other overt signs and symptoms may include hypertension, peripheral neuropathy, ataxia, tremor, headache, loss of appetite, weight loss, fatigue, muscle and joint aches, changes in behavior and concentration, gout, nephropathy, lead colic, and anemia. In general, symptoms tend to increase with increasing blood lead levels.

### 2.4.1 Impact on Sexual Maturation and Fertility

Although studies are limited, there is some suggestion that blood lead at relatively low levels may lead to alterations in the onset of sexual maturation and reduced fertility. These findings underscore the importance of considering sensitive markers of human fecundity in relation to lead exposure and should be confirmed in studies that can address the methodological limitations of previous research [54].

### 2.4.2 Impact on Maternal/Gestational Hypertension

Lead is an established risk factor for hypertension in adults [22, 55]. Hypertension is also one of the most common complications of pregnancy.

Gestational hypertension has been associated with adverse maternal and perinatal outcomes. Lead exposure has been associated with increased risk for gestational hypertension, but the magnitude of the effect, the exposure level at which risk begins to increase, and whether risk is most associated with acute or cumulative exposure remain uncertain.

### 2.4.3 Impact on Pregnancy Outcomes

Overall, increased risk for spontaneous abortion (miscarriage) appears to be associated with blood lead levels $\geq$30 μg/dL. Limited evidence suggests that maternal blood lead levels less than 30 μg/dL could also increase the risk for spontaneous abortion, although these findings remain to be confirmed in further research. Maternal lead exposure may increase the risk for preterm delivery and low birth weight, although data are limited and a blood lead level at which these risks begin to increase has not been determined. The available data are inadequate to establish the presence or absence of an association between maternal lead exposure and major congenital anomalies in the fetus [54].

### 2.4.4 Impact on Infant Growth and Neurodevelopment

Numerous studies on the association between prenatal lead exposure and infant growth have been conducted, but data is limited and thus it is difficult to make sweeping conclusions.

Two studies suggest an association between maternal lead exposure and decreased growth. In one study, maternal bone lead levels were negatively associated with infant weight at 1 month of age and with postnatal weight gain between birth and 1 month [56]. In another study, the postnatal linear growth rate was negatively related to prenatal blood lead level, although only when infants' postnatal lead exposure was also elevated [57].

The findings of recent cohort studies suggest that prenatal lead exposure at maternal blood lead levels below 10 μg/dL is inversely related to neurobehavioral development independent from the effects of postnatal exposure.

As previously noted, CDCP has not identified any threshold below which adverse effects of lead do not occur for either mother or fetus, instead, applying public health principles of prevention to intervene when prudent. Specific recommendations are presented throughout the rest of these guidelines.

## *2.5 Health Effects of Lead Exposure on Workers*

Workers who work with any lead-based materials—possible examples are construction or demolition work—are at higher risk for lead exposure. The potential for worker exposure to lead (as well as to other hazardous substances, safety hazards, and physical agents) also exists during all lead hazard control projects, efforts meant to remove or minimize lead hazards. Due to the recognized adverse health effects of lead, employers should minimize worker lead exposures as much as possible. Employers should refer directly to the OSHA construction lead standard (Sect. 5) for complete requirements.

Families of construction workers, including those involved in lead-based paint (LBP) activities, may also be exposed to lead brought home from the workplace. Studies suggest that construction workers' occupational lead exposures combined with ineffective hygiene practices can result in lead contamination of their cars and homes [58]. NIOSH and the New Jersey Department of Health conducted a surveillance study in 1993 and 1994 involving the voluntary participation of 46 construction workers' families. The workers, who had reported BLLs of 25 μg/dL, were identified from the 510 construction workers in the New Jersey ABLES registry [59]. BLL testing of young children indicated that the workers' children, particularly those under age six, were at greater risk of having elevated BLLs (10 μg/dL) than children in the general population. Higher percentages of workers' children in age categories 1–2 and 3–5 years had elevated BLLs than national averages for these ages.

There is also potential for take-home lead exposures among families of renovation and remodeling workers. Exposure to lead in construction activities can result in workers' vehicles being contaminated and a significant amount of lead being transported into the home. A NIOSH study of lead-exposed residential renovation and repair workers found higher surface lead levels in 20 full-time workers' vehicles (arithmetic mean: 3300 μg/m$^3$) than in those of 11 part-time volunteers (1500 μg/m$^3$), although the difference did not reach statistical significance [60].

## 3 Lead Hazard Abatement Methods

Once a lead hazard is discovered or determined, it should be removed or mitigated. The process for doing so is called abatement. According to the Lead-Based Paint Hazard Reduction Act of 1992, "abatement" refers to the methods used to permanently eliminate lead-based paint hazards or to make lead-based paint unavailable. HUD has defined "permanent" as lasting at least 20 years. US EPA defines a "paint-lead hazard" as:

1. Lead-based paint (LBP) on any friction surface that rubs against another surface and creates a dust-lead hazard
2. Lead-based paint that is damaged or deteriorated on any impact surface
3. Any chewable lead-painted surface on which there is evidence of teeth marks
4. Any other deteriorated lead-based paint on the inside or outside of any residential building or child-occupied facility

The term "abatement" includes a number of other ancillary activities that are not directly related to the removal of lead itself, but that must be included in the overall effort for the abatement to be successful. These activities include lead hazard evaluation, planning, cleaning, clearance, and waste disposal. When abatement is performed inadequately, or without sufficient protection, it can be even more harmful, causing lead exposures to increase.

Because lead abatement work is dangerous, all lead-based paint abatement contractors and firms must be certified to perform this type of work, and all abatement workers and supervisors must be trained and certified. Certification of abatement contractors and completion of clearance examinations by independent, certified risk assessors, lead-based paint inspectors, or sampling technicians ensures that abatement work is conducted properly and safely. The US EPA's regulations are generally implemented through state, tribal, or territorial programs.

There are four basic methods of lead abatement (Table 5.1):

1. Replacement—removing the building part coated with lead-based paint and replacing it with a new one
2. Enclosure—covering the lead-based paint with a solid barrier
3. Encapsulation—coating the lead-based painted surface so that it is not accessible
4. Paint removal

**Table 5.1** Comparison of four abatement methods

| Approach | Pros | Cons |
|---|---|---|
| *Replacement* | | |
| Removing lead-based painted components and replacing them with new "lead-free" components | Quick way to remove lead-based paint (LBP)<br>Permanent solution<br>Can improve building through upgrades<br>New component can lower heating bills and maintenance costs | May involve demolition work<br>Can create a lot of dust<br>Personal protection equipment (PPE) may be necessary |
| *Enclosure* | | |
| A rigid, mechanically affixed barrier<br>Surface preparation is necessary<br>"Source" problems must be fixed<br>LBP surfaces must be labeled<br>PPE may be needed | Uses locally available materials<br>Durable and long lasting<br>Low generation of waste and dust | LBP is still present<br>LBP may be disturbed during routine work on enclosure<br>Enclosed surfaces must be monitored for damage |
| *Encapsulation* | | |
| Uses a liquid, paint-like material<br>Surface preparation is critical<br>Must be strong but flexible<br>Must provide complete coverage over old paint<br>PPE may be needed | Little dust is generated<br>Lower cost than other abatement options<br>Many choices are available | Not appropriate for use on friction surfaces<br>Durability depends on condition of previous paint layers<br>Periodic monitoring and maintenance is required<br>Susceptible to water damage<br>Some systems may contain toxic ingredients |
| *Paint removal* | | |
| Takes off lead-based paint<br>Dust generation must be controlled<br>Wet scraping<br>Wet planning<br>Electric heat guns<br>Local exhaust hand tools<br>Chemical stripping | LBP is gone<br>Useful for historic preservation projects or detailed components<br>Many options are available | Tedious and time consuming<br>Dust is generated<br>Strippers create hazardous waste<br>Surface must be properly prepared for new surface |

*Source*: US EPA model worker course. March 2004 [61]

Enclosure and encapsulation do not remove the lead-based paint; they abate or mitigate the lead-based paint hazard. The four methods are described in detail below.

## 3.1 Abatement by Replacement

Replacement entails removing the lead-painted building component (such as a window) and replacing it with a new one that is not painted with lead-based paint. This method is mostly recommended for windows, doors, and other woodwork that has been coated with lead-based paint.

Replacement is the easiest and quickest way to get rid of lead-based paint. Replacement is a permanent solution and removes lead-based paint forever. When combined with overall modernization, replacement can upgrade the building itself.

Replacement is expensive and can be a lot of work. Skilled carpenters are often needed to put in the new parts—especially windows and doors. Surfaces next to the part being removed may also get damaged in the process. Replacement can involve manual demolition work which can create a lot of dust.

## 3.2 Abatement Using Enclosure

Enclosure involves covering the lead-based paint with a solid, dust-tight barrier so that it is completely enclosed. An enclosure keeps the lead-based paint away from the rest of the building and its building occupants.

The materials used to enclose the lead-painted surface must be durable. Common materials used to build enclosures include aluminum, fiber board, vinyl, plywood, drywall, tiles, and acrylic sheets.

Wallpaper and contact paper are not suitable enclosure materials because they are not dust-tight.

Enclosures are made using locally available construction materials and are usually affixed to the substrate using screws or nails or some other mechanical fastening system. Enclosures are durable and, if done right, don't create much waste or dust. They should typically last for at least 20 years under normal conditions.

Enclosure does not permanently remove the lead-based paint as the lead source still remains underneath the covering. Any subsequent renovation or repair work to enclosed surfaces will likely disturb the lead-based paint and release lead dust that has collected behind the enclosure barrier. Therefore, enclosed surfaces and joints of the enclosures must be periodically monitored for damage and deterioration.

## 3.3 Abatement by Encapsulation

Encapsulants are coatings of rigid materials that rely on adhesion to a lead-based painted surface instead of being mechanically fastened to the substrate. Encapsulation should not be confused with enclosure (described above), which involves mechanical fastening of rigid materials as the primary method of attachment.

Encapsulation is a process that makes lead-based paint inaccessible by providing a barrier between the lead-based paint and the environment. This barrier is formed using a liquid-applied coating or an adhesively bonded covering material. While encapsulant systems may also be attached to a surface by using supplemental mechanical fasteners, the primary means of attachment for an encapsulant is bonding of the coating or covering to the painted surface (either by itself or through the use of an adhesive).

Effective encapsulation depends upon a strong bond between the surface of the existing paint film and the encapsulant. However, this condition alone is not sufficient for encapsulation system success. All layers of the existing paint film must adhere well to each other, as well as to the base substrate. If not, the encapsulation system may fail. Thus, proper assessment of the suitability of the surface and substrate for encapsulation is essential prior to the application and installation of the product.

If the assessment shows significant surface deterioration, then encapsulation cannot be done, or the surface must undergo preparation for encapsulation; patch testing of the product should be done in the field before application. In addition to proper completion of preparation and application procedures, the encapsulated surface should be monitored by the owner and residents on an ongoing basis, with periodic reevaluation by a certified risk assessor.

Encapsulation technologies can offer safe and effective control of lead-based paint hazards and may be one of the only alternatives that can be used in certain situations because it is often less expensive.

Encapsulants may also be used in combination with other methods. Unless there is significant surface deterioration, encapsulants typically generate low amounts of leaded dust. However, if the encapsulation system fails, repairing the damage, as well as covering the exposed lead-based paint surfaces, may result in high maintenance costs.

Encapsulation's durability depends on the condition of previous paint layers. Field compatibility testing of the encapsulant with the particular lead-based painted surface is essential. Encapsulant system's success depends on proper surface preparation. Application may be weather and temperature dependent and may require several coats. Encapsulation can also be susceptible to water damage.

In recent years, encapsulation has been used less often than other abatement methods. The disadvantages appear to have outweighed the advantages in many cases.

## *3.4 Abatement by Lead Paint Removal*

Paint removal is the removal of lead paint from building components, leaving the substrate intact. More than any other abatement method, on-site paint removal involves the greatest degree of disturbance and dust generation. Therefore, on-site removal of lead-based paint from a substrate should be carried out only if abatement is required and if no other abatement method is feasible. Paint removal may increase the level of lead in household dust and make effective cleaning more difficult. Even if dust clearance standards are met, any increase in leaded dust levels, no matter how small, over baseline levels means some increase in exposure. Furthermore, all paint removal methods leave behind residues embedded in the substrate, which could continue to pose a hazard if the surface from which the paint is removed is later disturbed. Therefore, paint removal is the most invasive of abatement methods and should be avoided if possible.

In some cases, off-site paint removal can be an option, i.e., where the painted element is removed from the site and treated in a commercial or more controlled setting. This is a safer option for potential residents or neighbors of the building.

There are three methods of paint removal: mechanical, heat, and chemical.

### 3.4.1 Mechanical Methods

Mechanical methods (scraping, sanding, and blasting) are abrasive methods for removing paint from lead-based surfaces. They have two major drawbacks. They produce high levels of dangerous residue, and they have the potential to damage the underlying substrate.

#### 3.4.1.1 Scraping

Traditional scraping involves using hand tools to scrape the paint off the surface/substrate. It is a slow process that can remove lead coatings only with great effort. Aggressive scraping can gouge wooden surfaces and molding profiles. In general, scraping is best suited for use on completely flat surfaces.

Two kinds of scraping are available: wet and dry. Wet scraping entails misting loose paint with water before scraping it and continuing to mist with water while scraping. It is usually preferable to use wet scraping, as dry scraping creates a huge amount of dust. Wet scraping tends to create less dust than many other on-site paint removal methods; paint chips removed by scraping can be controlled much more easily than the more minute residue generated by other methods.

#### 3.4.1.2 Sanding

Sanding can be done manually with sandpaper or using power sanding tools (Fig. 5.1); both hand sanding and power sanding generate extremely high levels of paint dust. Rotary, disk, and belt sanding procedures, in addition to the problem of lead dust generation, can destroy carved work and molding profiles altogether. For these reasons, power sanding procedures are usually not appropriate for on-site surface preparation, especially in occupied buildings. The dust generated from sanding can permeate the building and endanger residents.

If the elements to be treated can be safely removed and taken to a controlled site for treatment, some sanding methods may be appropriate. Belt sanders can be used on flat surfaces, and orbital sanders, if used with great care, can be used with damage kept to a minimum. If off-site treatment is considered, proper care must be taken to remove features without damaging them. High-efficiency particulate air (HEPA)-equipped sanders, often used by professionals, help control the amount of lead dust put into the air. If power sanding is to be considered, HEPA equipment is strongly recommended. In addition, workers should also wear the HEPA mask shown in Fig. 5.2 for protection.


**Fig. 5.1** A typical power sanding tool


**Fig. 5.2** A typical HEPA filtration mask

#### 3.4.1.3 Blasting

All methods of abrasive blasting involve semi-controlled pulverization of the surface being treated. Under most conditions, the damage to the substrate will be irreparable [62]. It does not matter whether the blasting is dry or wet, fine grit or coarse grit, low pressure or high pressure, or whether the aggregate is sand, crushed walnut shells, glass beads, water, or air; abrasive blasting is destructive. Abrasive blasting will remove lead-based paint, but it will also create tremendous amounts of lead dust. The dust will permeate interior spaces, and in exterior applications it can be carried over a wide area, contaminating neighboring properties. Because of these potent hazards, abrasive blasting should never be used to remove lead paint.

### 3.4.2 Heat Methods

Lead-based paint can also be removed using a variety of heat (thermal) methods. Heat is applied to the paint, which softens it; the loosened paint can then be scraped off with hand tools. Certain tools, like blowtorches and other open-flame techniques, are extremely dangerous and should never be used [63]. In addition to the very real danger of burning down the building and the threat to human lives,


**Fig. 5.3** A typical heat gun

open-flame techniques produce very high levels of toxic lead dust and fumes that can be easily inhaled.

Heat guns (Fig. 5.3) and heat plates generate lower levels of heat than do torches. Electric heat guns may be used to force warmed air onto a painted surface. However, even at these lower levels of heat, there is still a danger of generating lead fumes and of igniting sawdust, construction debris, or other materials. Heat guns and heat plates should only be used under carefully controlled circumstances. Heat guns that generate heat of 1,100 °F or more are prohibited.

### 3.4.3 Chemical Methods

Standard paint-stripping chemicals include solvents (methylene chloride, Fig. 5.4) and caustics (sodium hydroxide or potassium hydroxide, Fig. 5.5). Methylene chloride is toxic and must be handled with appropriate precautions.

Methylene chloride is the basis for most solvent-based paint strippers. Methylene chloride is particularly effective on wooden surfaces because it causes little damage to wooden surfaces; it is often used for older buildings.

Caustic paint removers tend to be less toxic, but they have a greater tendency to pit wooden surfaces and raise wood grain.


**Fig. 5.4** A typical solvent-based paint stripper containing methylene chloride


**Fig. 5.5** A typical caustic paint stripper containing sodium hydroxide

Chemical methods generally generate much less paint dust than abrasive or thermal methods. Chemical stripping can be done on-site or off-site. Each procedure has its own problems and recommended precautions.

#### 3.4.3.1 On-Site Chemical Stripping

On-site chemical stripping must be done with great care, since residents or neighbors may be exposed to toxic chemicals. Good ventilation, protective clothing, and respirators are essential when using methylene chloride, since it can cause severe burns, liver and heart damage, and possibly cancer. There is also a danger of inhaling chemical fumes. Strict control over the worksite is essential when using this toxic chemical stripper.

The runoff from chemical stripping procedures is often hazardous as it can include lead paint residue, so even greater care must be taken to treat it accordingly and to dispose of it properly.

#### 3.4.3.2 Off-Site Chemical Stripping

In many cases, painted elements can be removed from buildings and treated at commercial stripping joints. Elements are immersed in tanks of chemical remover, either solvent based or caustic, scrubbed down, and then returned to the building. Because the work is done completely off-site, this method will not create the dust or fumes that are the chief hazard of on-site treatment, and the toxic chemicals are restricted to controlled areas. In fact, with respect to the health of workers and residents, any off-site method will always be safer than on-site removal. However, there are challenges associated with off-site treatment of affected architectural elements that are not an issue with on-site treatment. These include the need to limit the damage to the elements as they are removed, the proper reinstallation of the treated elements in their correct locations and configurations, and the limitations to the size of elements that can be removed for treatment.

## 4 Lead Hazard Abatement Operational Procedures

HUD published a report titled “Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing” (HUD 2012) that includes how-to-do-it recommendations for the abatement process, replacement of building components, enclosure, paint removal, and encapsulation [64]. These following checklists include each step that should be considered when undertaking any of these projects.

## *4.1 General Lead Hazard Abatement Process Procedures*

1. **Arrange for risk assessment or paint inspection.** Have a lead hazard risk assessment or lead-based paint inspection performed by a certified risk assessor or a certified inspector who is independent of the abatement contractor.
2. **Develop a hazard control plan.** Develop a site-specific lead hazard control plan based on the hazards (risk assessment) or lead-based paint (inspection) identified and financing available. Avoid high-dust jobs and procedures.
3. **Obtain waste permits.** Have the contractor obtain any necessary building or waste permits; notify local authorities if the local jurisdiction requires it.
4. **Select needed materials.** Together with the contractor (or designer or risk assessor), select specific building component replacement items, enclosure materials, paint removal equipment and/or chemicals, tools, and cleaning supplies. Consider waste management and historic preservation implications of the selected treatment.
5. **Develop specifications** (usually for large projects only).
6. **Schedule other construction work.** Schedule other needed construction work first so that leaded surfaces are not inadvertently disturbed and unprotected workers are not placed at risk. Include time for clearance examinations and laboratory dust sample analysis in the scheduling process.
7. **Select a contractor.** Select a certified abatement contractor using the lowest qualified bidder.
8. **Conduct preconstruction conference.** Conduct a preconstruction conference to ensure the contractor fully understands the work involved (for large projects only).
9. **Notify residents.** Notify residents of the dwelling and adjacent dwellings of the work and the date when it will begin. Implement relocation (if appropriate).
10. **Correct housing conditions that might impede work.** Correct any existing conditions that could impede the abatement work like trash removal or structural deficiencies.
11. **Post warning signs.** Post warning signs and restrict entry to authorized personnel only. Implement the worksite preparation procedures.
12. **Consider a pilot project.** For large projects only, consider conducting a pilot project to determine if the selected abatement method will actually work.
13. **Consider collecting soil samples for quality control.** As an optional quality control procedure, consider collecting pre- and post-abatement soil samples. Once collected, post-abatement soil samples should be analyzed and compared to clearance standards. The pre-abatement samples need not be analyzed if post-abatement soil levels are below the applicable limit. Soil sampling is not required by US EPA regulations as part of clearance. This is an optional activity.
14. **Execute construction work.** Execute abatement work. See step-by-step summaries for building component replacement, enclosure, paint removal, and encapsulation.

15. **Store waste.** Following completion of abatement work, be sure to store all waste in a secure area.
16. **Cleanup.** Conduct cleanup of the work site at the end of each day and final cleanup. Execute waste disposal.
17. **Arrange for clearance.** Have an independent certified inspector technician or risk assessor conduct a clearance examination. The clearance examination should be done after waiting at least 1 h after cleanup has been completed to allow dust to settle.
18. **Repeat cleaning if clearance fails.** If clearance is not achieved, repeat cleaning and/or complete abatement work before repeating the clearance examination. Once clearance is achieved, obtain any required formal release, if required by HUD or local authorities.
19. **Notify residents.** Notify residents of affected dwellings of the nature and results of the abatement work.
20. **Pay contractors.** Pay contractor and clearance examiner.
21. **Conduct periodic monitoring.** Following successful abatement, conduct periodic monitoring and reevaluation of enclosure or encapsulation systems (if applicable) or lead-based paint that was not abated. Maintain records of all abatement, monitoring, reevaluation, and maintenance activities, and turn them over to any new owner upon sale of the property as part of lead disclosure. Provide proper disclosure and notification to tenants.

## *4.2 Building Component Replacement Procedures*

1. Prepare work area and plan how the new component installation will be installed. Whenever possible, use new, energy-efficient window, door, and insulating systems.
2. Prepare lead-painted building component for removal. Turn off and disconnect any electrical circuits inside or near the building component to be removed.
3. Lightly mist the component to be removed.
4. Score all painted seams with a sharp knife.
5. Remove or bend back any screws, nails, or fasteners.
6. Dry component. Use a flat pry instrument (crowbar) and hammer to pry the component from the substrate.
7. Wrap and seal bulk components in plastic and take them to a covered truck for disposal or to secured waste storage area.
8. Vacuum any dust or paint chips in the area where the component was located.
9. Replace component (optional).
10. Conduct cleanup of the work site.
11. Arrange for clearance and reclean if necessary.

## 4.3 Enclosure Installation Procedures

1. Post warnings on affected components. Stamp, label, or stencil all lead-based painted surfaces that will be enclosed with a warning approximately every 2 ft (0.61 m) both horizontally and vertically on all components. The warning should read: "Danger: Lead-Based Paint." Deteriorated paint should not be removed from the surface to be enclosed.
2. Identify enclosure. Attach a durable drawing to the utility room or closet showing where lead-based paint has been enclosed in the dwelling.
3. Plan for annual monitoring of the enclosure by the owner.
4. Repair substrates. Repair any unsound substrates and structural elements that will support the enclosure, if necessary.
5. Select enclosure material. Select appropriate enclosure material. Acceptable choices include drywall or fiberboard, wood paneling, laminated products, rigid tile and brick veneers, vinyl, aluminum, or plywood.
6. Prepare electrical fittings. Install extension rings for all electrical switches and outlets that will penetrate the enclosure.
7. Clean floors. If enclosing floors, remove all dirt with a vacuum cleaner to avoid small lumps in the new flooring.
8. Seal seams. Seal and back-caulk all seams and joints. Back-caulking is the application of caulk to the underside of the enclosure.
9. Anchor enclosures. When installing enclosures directly to a painted surface, use adhesive and then anchor with mechanical fasteners (nails or screws).
10. Conduct cleanup.
11. Arrange for clearance. Have a certified risk assessor or inspector technician conduct clearance testing and provide documentation.

## 4.4 Lead Paint Removal Procedures

1. Decide on paint removal method—use only approved removal methods. Avoid the following prohibited methods: (a) open-flame burning or torching, (b) heat guns operating above 1100 °F, (c) machine sanding or grinding without a HEPA vacuum exhaust tool, (d) abrasive blasting or sandblasting without a HEPA vacuum exhaust tool, (e) paint stripping in a poorly ventilated space using volatile stripper, and (f) dry scraping (except for limited areas).
2. Ensure safe use of heat guns (Fig. 5.3)—for heat gun work, provide fire extinguishers in the work area and ensure that adequate electrical power is available. Use for limited areas only. Train workers to avoid gouging or abrading the substrate.
3. When using mechanical tools, use only HEPA-equipped tools—vacuum blasting and needle guns should not be used on wood, plaster, drywall, or other soft substrates. Observe the manufacturer's directions for the amount of vacuum airflow required.

4. Use a spray bottle or wet sponge for wet scraping to keep the surface wet while scraping—apply enough water to moisten the surface completely, but not so much that large amounts of water run onto the floor or ground. Do not moisten areas near electrical circuits.
5. Use off-site chemical stripping facilities, if feasible—for chemical paint removers, determine if the building component can be removed and stripped off-site. Off-site stripping is generally preferred to on-site paint removal. Observe all manufacturers' directions for use of paint removers.
6. Remove components carefully—score the component edges with a knife or razor blade to minimize damage to adjacent surfaces. Inform the off-site paint remover that lead-based paint is present before shipping. Wrap the component in plastic and send to the off-site stripping location.
7. Test effectiveness of on-site stripper, if used—for on-site paint removal, first test the product on a small area to determine its effectiveness. Chemical paint removers may not be effective or desirable on exterior, deteriorated wood surfaces, aluminum, and glass.
8. Stripping/removal—provide neoprene, nitrile, rubber, or polyvinyl chloride (PVC) gloves (or other types of glove recommended by the manufacturer), face shields, respirators with combination filter cartridges (Fig. 5.6) for leaded dust and organic vapors (if appropriate), and chemical-resistant clothing. Be sure to select the right type of organic vapor filter cartridge, gloves, or clothing for the specific chemical being used. Portable eyewash stations capable of providing a 15-min flow must be on-site. Apply the chemicals and wait the


**Fig. 5.6** A typical protection gear including face shield, respirator, and filter cartridges

required period of time. Maintain security overnight to prevent passersby from coming into contact with the chemicals. For caustic chemical paint removers (Fig. 5.5), neutralize the surface before repainting using glacial acetic acid (not vinegar).
9. Repaint with lead-free paint.
10. Dispose of waste properly.
11. Conduct cleanup.
12. Arrange for clearance—have a certified risk assessor or lead-based paint inspector conduct a clearance examination and provide documentation.

## *4.5 Encapsulation Procedures*

1. Determine if encapsulants can be used. Do not encapsulate the following surfaces: (a) friction surfaces, such as window jambs and doorjambs, (b) surfaces that fail patch tests, (c) surfaces with substrates or existing coatings that have a high level of deterioration, (d) surfaces in which there is a known incompatibility between two existing paint layers, (e) surfaces that cannot support the additional weight stress of encapsulation due to existing paint thickness, and (f) metal surfaces that are prone to rust or corrosion.
2. Conduct field tests of surfaces to be encapsulated for paint film integrity.
3. Consider special use and environmental requirements (e.g., abrasion resistance and ability to span base substrate cracks).
4. Examine encapsulant performance test data supplied by the manufacturer.
5. Conduct at least one on-site test patch on each type of building component where encapsulant will be used.
6. Prepare the surface selected for the complete job. For both non-reinforced and reinforced coatings, use a 6- by 6-in. ($15.24 \times 15.24$ cm) test patch area. Prepared surfaces for patch testing should be at least 2 in. larger in each direction than the patch area.
7. Use a 3- by 3-in. ($7.62 \times 7.62$ cm) patch for fiber-reinforced wall coverings. For rigid coatings that cannot be cut with a knife, conduct a soundness test.
8. Allow coating to cure and then assess results of the patch test. For liquid coating encapsulant, visually examine it for wrinkling, blistering, cracking, bubbling, or other chemical reaction with the underlying paint. Carry out the appropriate adhesion tests.
9. Record the results of all patch tests and decide which one to use.
10. Develop job specifications.
11. Implement a proper worksite preparation level.
12. Repair all building components and substrates as needed, e.g., caulk cracks, and repair sources of water leaks.
13. Prepare surfaces. Remove all dirt, grease, chalking paint, mildew and other surface contaminants, remnants of cleaning solutions, and loose paint. All surfaces should be deglossed as needed.

14. Ventilate the containment area whenever volatile solvents or chemicals are used.
15. Monitor temperature and humidity during encapsulant application or installation. For liquid coatings, monitor coating thickness to ensure that the encapsulant manufacturer's specifications are met.
16. Conduct cleanup and clearance.
17. Have the owner monitor the condition of the encapsulant after the first 6 months and at least annually thereafter to ensure it remains intact. Repairs should be made as necessary.
18. Provide information to owners and/or tenants on how to care for the encapsulation system properly and complete repairs safely and quickly.
19. Maintain accurate records. Make sure the records include: exact detailed locations of encapsulant applications, concentration of lead in the paint underneath the encapsulant, patch test specifications and results, reevaluations, product name, contractor, and date of application or installation, along with a copy of the product label and a material safety data sheet (MSDS) for the product. Record failures and corrective measures and signs of wear and tear.

## 5 Lead Hazard Abatement Practices

Below are the practices recommended by US Department of Housing and Urban Development with regard to lead abatement [64].

1. Develop a written compliance plan and designate a competent person to oversee worker protection efforts (usually an industrial hygienist or a certified lead abatement supervisor)—ensure that worker exposure to airborne lead during residential lead-related work does not exceed the permissible exposure limit (PEL) set by OSHA (50 μg/m$^3$ averaged over an 8-h period).
2. Conduct an exposure assessment for each job classification in each work area. Monitoring current work is the best means of conducting exposure assessments—perform air sampling of work that is representative of the exposure for each employee in the workplace who is exposed to lead. Alternatively, if working conditions are similar to previous jobs by the same employer within the past 12 months, previously collected exposure data can be used to estimate worker exposures. Finally, objective data (as defined by OSHA) may be used to determine worker lead exposures in some cases. Exposures to airborne leaded dust greater than 30 μg/m$^3$ (8-h, time-weighted average) trigger protective requirements.
3. Use specific worker protection measures—if lead hazard control will include manual demolition, manual scraping, manual sanding, heat gun use, or use of power tools such as needle guns that generate greater dust exposure, then specific worker protection measures are required until an initial exposure assessment is completed. If the initial exposure assessment indicates exposures

are less than 30 μg/m$^3$, the protection measures are not legally required, although exposure to lead should be kept as low as possible at all times.

4. Implement engineering, work practice, and administrative controls to bring worker exposure levels below the PEL—examples of such controls include the use of wet abatement methods, ventilation, and the selection of other work methods that generate less dust.
5. Supplement the use of engineering and work practice controls with appropriate respirators and implement a respiratory protection program where needed—provide a respirator to any employee who requests one, regardless of the degree of exposure, to prevent inhalation of lead-contaminated dust.
6. Conduct medical exams and fit testing for all workers who will be required to wear respirators—before work begins, medical exams should be arranged for each worker who will be required to wear a respirator. The exam entails fit testing, which will indicate whether the worker is physically capable of wearing a respirator safely.
7. Provide protective clothing and arrange for proper disposal or laundering of work clothing and proper labeling of containers of contaminated clothing and equipment.
8. Provide handwashing facilities with showers if exposures are over the PEL.
9. Implement a medical surveillance program that includes blood lead monitoring under the supervision of a qualified physician pursuant to OSHA regulations—initial blood testing for lead exposure is required by OSHA for workers performing certain tasks, such as manual scraping, whenever an exposure determination has not been completed, and for any worker who may be exposed to greater than 30 μg/m$^3$ of lead on any day.
10. Ensure that workers are properly trained in the hazards of lead exposure, the location of lead-containing materials, the use of job-specific exposure control methods (such as respirators), the use of hygiene facilities, and the signs and symptoms of lead poisoning—OSHA requires all lead hazard control workers to be trained and to be given (communicated) specific information on lead hazards for the specific job they are doing. Employers are responsible for training their employees to comply with all of OSHA's construction standards, not just the lead standard; this training needs to be worksite specific.
11. Post lead hazard warning signs around work areas. Also, post an emergency telephone number in case an on-the-job injury occurs.
12. Conduct work as specified.
13. Conduct worker decontamination before all breaks, before lunch, and at the end of each shift—decontamination of workers performing abatement usually consists of:

    (a) Cleaning all tools in the work area or a specially designated area in the restricted work area (end of the shift only);
    (b) HEPA vacuuming all protective clothing if visibly contaminated with paint chips or dust before entering the decontamination area;
    (c) Entering the decontamination area (dirty side);

(d) Removing protective clothing by rolling outward (without removing the respirator), removing work shoes, and placing them in a plastic bag;
(e) Entering shower or washing facility;
(f) Washing hands and then removing respirator;
(g) Taking a shower, if available, using plenty of soap and water, and washing hair, hands, fingernails, and face thoroughly (before lunch and at the end of the shift only); and
(h) Entering the clean area and putting on street clothing and shoes

14. Review and maintain exposure assessment and medical surveillance records continuously for 30 years—notify workers of air sampling and blood lead level results within 5 working days after receiving the results. Provide each worker with a copy of the written medical opinion from their examining physician. Employers must maintain all records of exposure monitoring for 30 years and all medical records for the duration of each worker's employment plus 30 years.

# 6 Risk Management

## *6.1 Risk Assessment*

Risk assessment is a procedure for determining the existence, nature, severity, and location of lead-based paint hazards in or on a residential property; it also includes reporting the findings of the assessment and the options for controlling or abating the hazards that are found.

Legally, risk assessments are on-site investigations by licensed professionals to determine the existence, nature, severity, and location of lead-based paint hazards accompanied by a report explaining the results and options for reducing lead-based paint hazards (40 CFR 745.227(d)(11)). A lead-based paint hazard is any condition that causes exposure to lead from dust-lead hazards, soil-lead hazards, or lead-based paint that is deteriorated or present in chewable surfaces, friction surfaces, or impact surfaces that would result in adverse human health effects. A risk assessment may be conducted in any residential property, regardless of occupancy. However, in the case of an environmental investigation of the home of a child with an elevated blood lead level (EBL), the standard risk assessment should be supplemented with additional questions and activities.

Activities that are required by US EPA or HUD regulations are identified in this section as being "required" or as actions that "must" be done. Activities that are not required by US EPA or HUD regulations but are recommended are identified as being "recommended" or as actions that "should" be done. Note that there may be state, tribal, or local laws and regulations that must also be followed, especially if

they are more stringent or protective than the federal requirements. Activities that may be done at the discretion of the owner or manager are identified as "optional." Section 6.4 discusses risk assessment further.

## 6.2 Risk Evaluation Options

This section offers owners, planners, and risk assessors guidance on choosing the most appropriate evaluation method for specific housing situations. There are other types of evaluation aside from a risk assessment. Except where regulations specifically require a risk assessment or a lead-based paint inspection, there are no simple rules for choosing an evaluation method.

A property owner has a choice of the following evaluation options, except where regulations limit or determine the choice:

1. A risk assessment, which identifies lead-based paint hazards, as defined by US EPA regulations
2. A lead hazard screen (for properties in good physical condition)
3. A lead-based paint inspection, which identifies all lead-based paint, whether hazardous or not
4. A combination risk assessment/paint inspection, which provides complete information on lead-based paint and lead-based paint hazards

Tables 5.2 and 5.3 provide an overview comparing two options: (a) risk assessment and lead hazard screen and (b) lead-based paint inspection and combination inspection/risk assessment.

## 6.3 Lead Hazard Screen

A second type of lead-based paint evaluation is the lead hazard screen. This evaluation method identifies lead-based paint hazards like the risk assessment does, but it also identifies other potential lead hazards. It is an abbreviated form of evaluation and generally is available at a lower cost than a full risk assessment. However, this method should be used only in dwellings in good condition where the probability of finding lead-based paint hazards is low. A screen employs limited sampling (soil sampling is usually not conducted) and, as a trade-off, more sensitive hazard identification criteria. The protocol for a lead hazard screen is described later in this chapter. If a screen indicates that lead hazards may be present, the owner should have a full risk assessment performed. All lead hazard screens must be performed by risk assessors certified or licensed by US EPA or an US EPA-authorized state, tribe, or territory.

**Table 5.2** Comparison of risk assessment and lead hazard screen

| Analysis, content, or use | Risk assessment | Lead hazard screen |
|---|---|---|
| Paint | Deteriorated paint and intact paint on friction and impact surfaces only | Deteriorated paint only |
| Dust | Yes | Yes |
| Soil | Yes | No |
| Water | Optional | No |
| Air | No | No |
| Maintenance status | Optional | No |
| Management plan | Optional | No |
| Status of any current child lead poisoning cases | If information is available | If information is available |
| Review of previous paint testing | Yes | Yes |
| Typical applications | 1. Interim controls<br>2. Building nearing the end of expected life<br>3. Sale of property or turnover<br>4. Insurance (documentation of lead-safe status)<br>5. Remodeling and repainting<br>6. Lead Safe Housing Rule compliance | Post-1960 housing in good condition for which a risk assessment is required |
| Final report | Location of lead-based paint hazards and options for acceptable hazard control methods or certification that no lead-based paint hazards were found. Also includes interim controls and abatement measures if hazards are found | Probable existence of lead-based paint hazards (based on more stringent standards used for screen) or the absence of lead-based paint hazards |

*Source*: Guidelines for the evaluation and control of lead-based paint hazards in housing [64]

## *6.4 Lead-Based Paint Inspection*

The third type of evaluation is a paint inspection. It evaluates all painted surfaces to detect any presence of lead-based paint and must be done by a certified paint inspector.

HUD [64] recommends the following step-by-step process for a comprehensive risk assessment:

1. Determine scope. Determine if the client is requesting a risk assessment, a lead-based paint inspection, lead hazard screen, or a combination of the two. Reach an agreement on costs and scope of effort. If the dwelling is in good condition, a lead hazard screen may be conducted to determine if a full risk assessment is needed.

**Table 5.3** Comparison of lead-based paint inspection and combination inspection/risk assessment

| Analysis, content, or use | Lead-based paint inspection | Combination inspection/risk assessment |
|---|---|---|
| Paint | Surface-by-surface | Surface-by-surface |
| Dust | Yes | Yes |
| Soil | No | Yes |
| Water | No | Optional |
| Air | No | No |
| Maintenance status | No | Optional |
| Management plan | No | Optional |
| Status of any current child lead poisoning cases | No | If information is available |
| Review of previous paint testing | Yes | Yes |
| Typical applications | 1. Abatement<br>2. Renovation work<br>3. Weatherization<br>4. Sale of property or turnover | Renovation |
| Final report | Lead concentration for each painted building component | Combination of risk assessment and inspection report content |

*Source*: Guidelines for the evaluation and control of lead-based paint hazards in housing [64]

2. Interview residents and/or owners. For individual residences, interview residents about family use patterns, especially of young children (if any).
3. Survey building condition. Perform a brief building condition survey to identify any major deficiencies that may affect the success of lead hazard controls.
4. Determine whether units will be sampled and, if so, select units. Visual assessments and environmental sampling should be conducted in each dwelling if assessing individual dwelling units, fewer than five rental units, or multiple rental units where the units are not similar.
5. Conduct visual assessment. Perform a visual assessment of the building and paint condition, using the forms and protocols in this chapter, and select dust sampling and paint testing locations based on use patterns and visual observations.
6. Conduct dust sampling: (a) in individual dwelling units, dust samples are typically collected in the entryway and at least four living areas where children under age 6 are most likely to come into contact with dust (such as the kitchen, the children's principal playroom, and children's bedrooms); (b) in multifamily properties, dust samples are also collected from the common areas, including main entryway, stairways, and hallways, and other common areas frequented by a young child; (c) submit dust samples to a laboratory recognized for the analysis of lead in dust by US EPA through the National Lead Laboratory Accreditation Program (NLLAP).
7. Conduct soil sampling. Collect a composite soil sample from bare soil in each of the three following area types: (a) each play area with bare soil, (b) nonplay

areas in the foundation area, and (c) nonplay areas in the rest of the yard (including gardens).
8. Conduct paint testing as needed. Conduct testing of deteriorated paint and intact paint on friction surfaces. Lead in deteriorated paint can be measured with a portable x-ray fluorescence (XRF) analyzer if there is a large enough flat surface with all layers present.
9. Sample tap water (optional). At the client's request, collect optional water samples to evaluate lead exposures that can be corrected by the owner (leaded service lines, fixtures). Water sampling is not recommended for routine risk assessments of lead-based paint hazards, since drinking water hazards are outside the scope of lead-based paint hazards, and US EPA has another program that regulates drinking water. US EPA has a protocol, including specific sample collection procedures and when to collect the samples, which should be followed.
10. Interpret the laboratory results. Interpret the results of the environmental testing in accordance with applicable regulations.
11. Analyze data and discuss with client. Integrate the laboratory results with the visual assessment results, any XRF measurements, and other maintenance and management data to determine the presence or absence of lead-based paint hazards, as defined under applicable statutes or regulations.
12. Prepare a report listing any hazards identified and acceptable control measures, including interim control and abatement options.
13. Discuss all of the safe and effective lead hazard control options, and provide recommendations, for specific lead hazards with the owner.

# 7 Lead Hazard Control Planning

## *7.1 Long-Term or Short-Term Response*

Owners have a wide range of options for lead hazard evaluation and control that include both long- to short-term solutions.

Complete and permanent elimination of all known or presumed lead-based paint through abatement is a long-term approach. It can be effective and safe provided that:

1. All types of lead hazards are addressed, including lead-contaminated dust and soil.
2. Workers and residents are not adversely affected during the work.
3. The process is properly controlled so that new lead hazards are not created.
4. Cleanup is adequate as determined by clearance testing.

Risk assessment followed by abatement of specific lead-based paint hazards is a more focused long-term approach. It focuses treatment resources on specific hazards. If encapsulation or enclosure is performed, the condition of these treatments

should be periodically monitored through a lead-safe maintenance program. Short-term solutions are only appropriate as an interim measure.

### *7.2 Lead Hazard Control Planning Steps*

1. Review of existing conditions and preliminary determination of lead hazard control strategy, including historic preservation considerations
2. Evaluation of lead-based paint and/or lead-based paint hazards
3. Preparation of notice of evaluation for the presence of lead to residents, if required
4. Selection of specific lead hazard control methods
5. Selection of level of resident protection and worksite preparation level
6. Initiation of pilot project (not necessarily required in single-family dwellings)
7. Scheduling of other related construction work
8. Selection of lead hazard control contractors. Notifications to state/local jurisdictions, if required
9. Lead-safe correction of preexisting conditions that could impede lead hazard control work
10. Ongoing monitoring of the work and cleanup process
11. Clearance (and certification if required by the local jurisdiction)
12. Preparation of format for notice of lead hazard control activities to residents, if required
13. Arrangement of ongoing monitoring and reevaluation after completion of lead control project

## 8 Rules and Regulations for Lead Poisoning Prevention and Environmental Control

### *8.1 Worldwide Awareness and Regulations*

Lead-laden paints are still widely sold around the world due to their durability, corrosion resistance capability, and low cost. However, the European Union (EU) has passed a directive controlling the use of lead-based paint. The Canadian government has also established rules and regulations on surface-coating materials, which came into force in 2005, limiting lead content to its background level for both interior and exterior paints sold to consumers [49].

In the USA, the US EPA, HUD, and OSHA all have rules and regulations for lead in their respective areas (i.e., environmental concerns, housing, and the workplace). As previously mentioned, states may also have their own individual regulations.

The US Congress passed the Residential Lead-Based Paint Hazard Reduction Act of 1992, also known as Title X, to protect families from exposure to lead from paint, dust, and soil. Section 1018 of this law directed HUD and US EPA to require the disclosure of known information on lead-based paint and lead-based paint hazards before the sale or lease of most housing built before 1978. Before ratification of a contract for housing sale or lease, sellers and landlords must:

1. Supply a US EPA-approved information pamphlet on identifying and controlling lead-based paint hazards.
2. The seller or landlord must disclose any known information concerning lead-based paint or lead-based paint hazards, such as the location of the lead-based paint and/or lead-based paint hazards, and the condition of the painted surfaces.
3. Provide any records and reports on lead-based paint and/or lead-based paint hazards that are available to the seller or landlord (For multi-unit buildings, this requirement includes records and reports concerning common areas and other units obtained as a result of a building-wide evaluation).
4. Include an attachment to the contract or lease (or language inserted in the lease itself) that includes a Lead Warning Statement and confirms that the seller or landlord has complied with all notification requirements. This attachment is to be provided in the same language used in the rest of the contract. Sellers or landlords, and agents, as well as homebuyers or tenants, must sign and date the attachment.
5. Sellers must provide homebuyers a 10-day period to conduct a paint inspection or risk assessment for lead-based paint or lead-based paint hazards. Parties may mutually agree, in writing, to lengthen or shorten the time period for inspection. Homebuyers may waive this inspection opportunity.

The Lead Disclosure Rule (the identical 24 CFR 35, subpart A, and 40 CFR 745, subpart F) was jointly issued by HUD and US EPA in 1996 (61 FR 9063-9088, March 6, 1996) as part of Title X. As of 2011, HUD and US EPA had issued three interpretive guidance documents about the Lead Disclosure Rule; these are available from both agencies' websites on the rule.

## *8.2 OSHA's Lead Regulations*

OSHA's lead regulations are described at OSHA's main lead regulation web page at: http://www.osha.gov/SLTC/lead/. In addition, as of 2014, 25 states, Puerto Rico, and the Virgin Islands had OSHA-approved State Plans and had adopted their own standards and enforcement policies. For the most part, these states adopted standards similar to OSHA's. However, some states have adopted different standards or have different enforcement policies.

OSHA has two lead standards, one specifically for construction and one for general industry. The two standards complement each other. The first covers construction work (construction, alteration, repair, painting, and/or decorating (29 CFR 1926.10, (a))), while the second covers work that is not related to

construction work (such as maintenance work). Employers are responsible for determining which standard applies to their workers on a particular project.

### 8.2.1 OSHA's Lead in Construction Standard

OSHA's Lead in Construction Standard (29 CFR 1926.62) applies to all construction work where an employee may be occupationally exposed to lead. OSHA has published a 332-page booklet on this regulation (OSHA 3142-09R 2003), posted at http://www.osha.gov/Publications/osha3142.pdf. OSHA has also posted an online interactive expert system (compliance advisor) on the Lead in Construction Standard at http://www.dol.gov/elaws/oshalead.htm.

The Lead in Construction Standard applies to any source or concentration of lead to which workers may be exposed as a result of construction work. OSHA standards are not limited to lead-based paint as defined by HUD or US EPA or lead-containing paint as defined by the Consumer Product Safety Commission (CPSC). All work related to construction, alteration, or repair, including painting and decorating, is included. Under this standard, construction includes but is not limited to:

1. Demolition or salvage of structures where lead or materials containing lead are present
2. Removal or encapsulation of materials containing lead
3. New construction, alteration, repair, or renovation of structures, substrates, or portions or materials containing lead
4. Installation of products containing lead
5. Lead contamination from emergency cleanup
6. Transportation, disposal, storage, or containment of lead or materials containing lead where construction activities are performed
7. Maintenance operations associated with these construction activities

### 8.2.2 OSHA's Lead in General Industry Standard

The OSHA's Lead in General Industry Standard (29 CFR 1910.1025) covers the use of lead in general industry. This industry includes nonconstruction-related maintenance work, as well as lead smelting, manufacturing, and the use of lead-based pigments contained in inks, paints, and other solvents in addition to the manufacturing and recycling of lead batteries.

Maintenance work associated with construction, alteration, or repair activities is covered separately by the Construction Standard (29 CFR 1926.62, subsection (a), as discussed below). Nonconstruction-related maintenance work (or if lead is a component of any product that workers make or use) is covered by the General Industry Standard (29 CFR 1910.1025(e)(3)(ii)(A)). Construction activities do not include routine cleaning and repainting where there is insignificant damage, wear, or corrosion of existing lead-containing paint and coating or substrates.

## 8.3 Summary of All US Federal Lead Standards

### 8.3.1 Lead Content Standards

OSHA, US EPA, CDC, NIOSH, FDA, CPSC, and ACGIH have issued various lead standards for blood (OSHA, CDC, ACGIH), air (OSHA, CDC/NIOSH, ACGIH, US EPA), water (US EPA), soil (US EPA), paint (CPSC), and food (FDA). Table 5.4 is a summary of the standards for different media, agencies, allowable levels, and comments for applicability. For example, Table 5.4 shows that (a) the CDC advisory's lowest blood level is 10 μg/dL for individual management, (b) the US EPA regulated NAAQS for the lowest ambient air lead level is 0.15 μg/m$^3$ (3-month average), (c) the US EPA's residential play area's soil lead level is limited at 400 ppm, and (d) the action level for public water supplies is set at 15 μg/L by the US EPA.

In the USA, Consumer Product Safety Commission (CPSC) formally banned lead-based paint (LBP) in residential properties and public buildings along with toys and furniture containing lead paint in 1977, because children may ingest lead paint chips or peelings and be poisoned [66]. The CPSC also instituted the

**Table 5.4** Standard and regulation for lead content

| Media | Agency | Level | Comments |
|---|---|---|---|
| Blood | OSHA | 40 μg/dL<br>60 μg/dL | Regulation<br>Regulation, cause for medical removal from exposure |
| Blood | CDC | 10 μg/dL | Advisory, level for individual management |
| Blood | ACGIH | 30 μg/dL | Advisory, indicates exposure at the TLV |
| Air (workplace) | CDC/ NIOSH | 100 μg/m$^3$ | REL (non-enforceable) |
| Air (workplace) | OSHA | 50 μg/m$^3$<br>30 μg/m$^3$ | Regulation, PEL (8-h average) (general industry)<br>Action level |
| Air (ambient) | US EPA | 0.15 μg/m$^3$ | Regulation, NAAQS, 3-month average |
| Air (workplace) | ACGIH | 150 μg/m$^3$<br>50 μg/m$^3$ | TLV/TWA guideline for lead arsenate<br>TLV/TWA guideline for other forms of lead |
| Water (drinking) | US EPA | 15 μg/L<br>0 μg/L | Action level for public supplies<br>Non-enforceable goal, MCLG |
| Soil (residential) | US EPA | 400 ppm (play areas)<br>1200 ppm (nonplay areas) | Soil screening guidance level, requirement for federally funded projects only |
| Paint | CPSC | 600 ppm (0.06 %) | Regulation, by dry weight. There is a new standard for lead in children's jewelry |
| Food | FDA | Various | Action levels for various foods, for example, lead-soldered food cans now banned |

*Source*: Case Studies in Environmental Medicine (CSEM) lead toxicity (2012) [65] http://www.atsdr.cdc.gov/csem/lead/docs/lead.pdf

Consumer Product Safety Improvement Act (CPSIA) of 2008 for manufacturers. The CPSIA changed the cap on lead content in paint from 0.06 % to 0.009 % starting August 14, 2009.

### 8.3.2 US EPA Lead Renovation, Repair, and Painting Rule

US EPA's 2008 Lead-Based Paint Renovation, Repair and Painting (RRP) Rule (as amended in 2010 and 2011), aims to protect the public from lead-based paint hazards associated with renovation, repair, and painting activities. These activities can create hazardous lead dust when surfaces with lead paint, even from many decades ago, are disturbed. The rule requires workers to be certified and trained in the use of lead-safe work practices and requires renovation, repair, and painting firms to be US EPA certified. These requirements became fully effective on April 22, 2010. Specifically the RRP Rule requires that (a) all renovators working in homes built before 1978 and disturbing more than 6 $ft^2$ (0.557 $m^2$) of lead paint inside the home or 20 $ft^2$ (1.858 $m^2$) outside the home be certified; (b) firms performing renovation, repair, and painting projects that disturb lead-based paint (LBP) in homes and any child-occupied facility (child care facilities, preschools, etc.) built before 1978 be certified by US EPA; (c) the certified renovators be trained by the US EPA-approved training providers; and (d) only the certified renovators be used for lead remediation projects [67].

## 9 New York State Lead Poisoning Prevention and Control Programs

Almost all states in the USA have established their own lead poisoning prevention and control programs [68–70] with collaboration of the US Federal government [71–72]. As a model example, this section introduces the New York State's lead programs that are part of the New York Codes, Rules, and Regulations (NYCRR). The information contained in this section is not the official, final version of the NYCRR's compilation. No representation is made as to its accuracy. Furthermore, the NYCRR is only valid in the State of New York and is subject to revision periodically. To ensure accuracy and for evidentiary purposes, readers should obtain the most current and site-specific version from the government which has direct the jurisdiction.

### *9.1 New York State (NYS) Lead Poisoning Prevention Program*

1. The New York State Department of Health (NYSDOH) has established a lead poisoning prevention program, which is responsible for establishing and coordinating activities to prevent lead poisoning and to minimize risk of exposure to

lead. NYSDOH exercises any and all authority which may be deemed necessary and appropriate to effectuate the provisions of this title.

2. NYSDOH:

   (a) Promulgates and enforces regulations for screening children and pregnant women, including requirements for blood lead testing, for lead poisoning, and for follow-up of children and pregnant women who have elevated blood lead levels;
   (b) Enters into interagency agreements to coordinate lead poisoning prevention, exposure reduction, identification and treatment activities, and lead reduction activities with other federal, state, and local agencies and programs;
   (c) Establishes a statewide registry of lead levels of children provided such information is maintained as confidential except for (c-i) disclosure for medical treatment purposes; (c-ii) disclosure of non-identifying epidemiological data; and (c-iii) disclosure of information from such registry to the statewide immunization information system; and
   (d) Develops and implements public education and community outreach programs on lead exposure, detection, and risk reduction

3. NYSDOH identifies and designates areas in the state with significant concentrations of children identified with elevated blood lead levels as communities of concern for purposes of implementing a childhood lead poisoning primary prevention program and may, within amounts appropriated, provide grants to implement approved programs. The commissioner of health of a county or part-county health district, a county health director or a public health director, and, in the City of New York, the commissioner of the New York City Department of Health and Mental Hygiene shall develop and implement a childhood lead poisoning primary prevention program to prevent exposure to lead-based paint hazards for the communities of concern in their jurisdiction. NYSDOH provides funding to the New York City Department of Health and Mental Hygiene or County Health Departments to implement the approved work plan for a childhood lead poisoning primary prevention program. The work plan and budget, which shall be subject to the approval of the department, shall include but not be limited to:

   (a) Identification and designation of an area or areas of high risk within communities of concern;
   (b) A housing inspection program that includes prioritization and inspection of areas of high risk for lead hazards, correction of identified lead hazards using effective lead-safe work practices, and appropriate oversight of remediation work;
   (c) Partnerships with other counties or municipal agencies or community-based organizations to build community awareness of the childhood lead poisoning primary prevention program and activities, coordinate referrals for services, and support remediation of housing that contains lead hazards;

(d) A mechanism to provide education and referral for lead testing for children and pregnant women to families who are encountered in the course of conducting primary prevention inspections and other outreach activities; and
(e) A mechanism and outreach efforts to provide housing inspections for lead hazards upon request

## *9.2 NYS Advisory Council on Lead Poisoning Prevention Program*

### 9.2.1 Designees of NYS Advisory Council

The New York State (NYS) advisory council on lead poisoning prevention is established in the NYSDOH, to consist of the following or their designees: the commissioner, the commissioner of labor, the commissioner of environmental conservation, the commissioner of housing and community renewal, the commissioner of children and family services, the commissioner of temporary and disability assistance, the secretary of state, the superintendent of insurance, and 15 public members appointed by the governor. The public members shall have a demonstrated expertise or interest in lead poisoning prevention, and at least one public member shall be representative of each of the following: local government, community groups, labor unions, real estate, industry, parents, educators, local housing authorities, child health advocates, environmental groups, and professional medical organizations and hospitals. The public members of the council shall have fixed terms of 3 years, except that five of the initial appointments shall be for 2 years and five shall be for 1 year. The council shall be chaired by the commissioner or his or her designee. Members of the advisory council shall serve without compensation for their services, except that each of them may be allowed necessary and actual expenses which he or she shall incur in the performance of his or her duties under this article.

### 9.2.2 Powers and Duties of NYS Advisory Council

The council shall meet as often as may be deemed necessary to fulfill its responsibilities. The council shall have the following powers and duties:

1. To develop a comprehensive statewide plan to prevent lead poisoning and to minimize the risk of human exposure to lead.
2. To coordinate the activities of its member agencies with respect to environmental lead policy and the statewide plan.
3. To recommend the adoption of policies with regard to the detection and elimination of lead hazards in the environment.
4. To recommend the adoption of policies with regard to the identification and management of children with elevated lead levels.

5. To recommend the adoption of policies with regard to education and outreach strategies related to lead exposure, detection, and risk reduction.
6. To comment on regulations of the department under this title when the council deems appropriate.
7. To make recommendations to ensure the qualifications of persons performing inspection and abatement of lead through a system of licensure and certification or otherwise.
8. To recommend strategies for funding the lead poisoning prevention program, including but not limited to ways to enhance the funding of screening through insurance coverage and other means, and ways to financially assist property owners in abating environmental lead, such as tax credits, loan funds, and other approaches.
9. To report on or before the first of December of each year to the governor and the legislature concerning the previous year's development and implementation of the statewide plan and operation of the program, together with recommendations it deems necessary and the most currently available lead surveillance measures, including the actual number and estimated percentage of children tested for lead in accordance with New York state regulations, including age-specific testing requirements, and the actual number and estimated percentage of children identified with elevated blood lead levels. Such report shall be made available on the department's website.

## *9.3 Lead Screening of Children and Pregnant Women by NYS Health-Care Providers*

1. NYSDOH is authorized to promulgate regulations establishing the means by which and the intervals at which children and pregnant women shall be screened for elevated lead levels. The department is also authorized to require screening for lead poisoning in other high-risk groups.
2. Every physician or other authorized practitioner who provides medical care to children or pregnant women shall screen children or refer them for screening for elevated lead levels at the intervals and using the methods specified in such regulations. Every licensed, registered, or approved health-care facility serving children including but not limited to hospitals, clinics, and health maintenance organizations shall ensure, by providing screenings or by referring for screenings, that their patients receive screening for lead at the intervals and using the methods specified in such regulations.
3. The health practitioner who screens any child for lead shall give a certificate of screening to the parent or guardian of the child.
4. The department shall establish a separate level of payment, subject to the approval of the director of the budget, for payments made by governmental agencies for screenings performed pursuant to this section by hospitals.

## 9.4 Lead Screening of Child Care or Preschool Enrollees in NYS

1. Except as provided pursuant to regulations of the NYSDOH, each child care provider, public and private nursery school, and preschool licensed, certified, or approved by any state or local agency shall, prior to or within 3 months after initial enrollment of a child under 6 years of age, obtain from a parent or guardian of the child evidence that said child has been screened for lead.
2. Whenever there exists no evidence of lead screening as provided for in subdivision one of this section or other acceptable evidences of the child's screening for lead, the child care provider, principal, teacher, owner, or person in charge of the nursery school or preschool shall provide the parent or guardian of the child with information on lead poisoning in children and lead poisoning prevention and refer the parent or guardian to a primary care provider or the local health authority.
3. (a) If any parent or guardian to such child is unable to obtain lead testing, such person may present such child to the health officer of the county in which the child resides, who shall then perform or arrange for the required screening. (b) The local public health district shall develop and implement a fee schedule for households with incomes in excess of 200 % of the federal poverty level for lead screening pursuant to section six hundred six of this chapter, which shall vary depending on patient household income.

## 9.5 Reporting Lead Exposure Levels in NYS

1. Every physician or authorized practitioner shall give notice of elevated lead levels as specified by the commissioner pursuant to regulation, to the health officer of the health district wherein the patient resides, except as otherwise provided.
2. The commissioner may, by regulation, provide that cases of elevated lead levels which occur (a) in health districts of less than 50,000 population not having a full-time health officer or, (b) in state institutions, shall be reported directly to the department or its district health officer.
3. Whenever an analysis of a clinical specimen for lead is performed by a laboratory or a physician or authorized practitioner, the director of such laboratory or such physician or authorized practitioner shall, within such period specified by the commissioner, report the results and any related information in connection therewith to the local and state health officer to whom a physician or authorized practitioner is required to report such cases, pursuant to this section.
4. The person in charge of every hospital, clinic, or other similar public or private institution shall give notice of every child with an elevated blood lead level coming under the care of the institution to the local or state health officer to

whom a physician or authorized practitioner is required to report such cases, pursuant to this section.
5. The notices required by this section shall be in a form and filed in such time period as shall be prescribed by the commissioner.

## 9.6 Manufacture and Sale of Lead-Painted Toys and Furniture in NYS

1. No person shall manufacture, sell, or hold for sale a children's toy or children's furniture having paint or other similar surface-coating materials thereon containing more than 0.06 of one per centum of metallic lead based on the total weight of the contained solids or dried paint film.
2. The commissioner of health may waive the provisions of this section in whole or in part upon a finding by the commissioner in a particular instance that there is no significant threat to public health; with respect to miniatures the commissioner shall do so, on terms and conditions he or she shall establish, upon a final judicial or administrative finding that there is no immediate public health threat in that instance.

## 9.7 Use of Leaded Paint in NYS

No person shall apply paint or other similar surface-coating materials containing more than 0.06 of one per centum of metallic lead based on the total weight of the contained solids or dried paint film to any interior surface, window sill, window frame, or porch of a dwelling.

## 9.8 Abatement of Lead Poisoning Conditions in NYS

1. Whenever the commissioner or his representative shall designate an area of high risk, he may give written notice and demand, served as provided herein, for the discontinuance of a paint condition conducive to lead poisoning in any designated dwelling in such area within a specified period of time.
2. Such notice and demand shall prescribe the method of discontinuance of a condition conducive to lead poisoning which may include the removal of paint containing more than one-half of one per centum of metallic lead based on the total weight of the contained solids or dried film of the paint or other similar surface-coating materials from surfaces specified by the commissioner or his/her representative under such safety conditions as may be indicated, and the refinishing of such surfaces with a suitable finish which is not in violation of

section one thousand three hundred seventy-two of this title, or the covering of such surfaces with such material or the removal of lead-contaminated soils or lead pipes supplying drinking water, as may be deemed necessary to protect the life and health of occupants of the dwelling.

3. In the event of failure to comply with a notice and demand, the commissioner or his/her representative may conduct a formal hearing upon due notice in accordance with the provisions of section twelve-a of this chapter and, on proof of violation of such notice and demand, may order abatement of a paint condition conducive to lead poisoning upon such terms as may be appropriate and may assess a penalty not to exceed 2,500 US dollars for such violation.
4. A notice required by this section may be served upon an owner or occupant of the dwelling or agent of the owner in the same manner as a summons in a civil action or by registered or certified mail to his last known address or place of residence.
5. The removal of a tenant from or the surrender by the tenant of a dwelling with respect to which the commissioner or his representative, pursuant to subdivision one of this section, has given written notice and demand for the discontinuance of a paint condition conducive to lead poisoning shall not absolve, relieve, or discharge any persons chargeable therewith from the obligation and responsibility to discontinue such paint condition conducive to lead poisoning in accordance with the method of discontinuance prescribed therefor in such notice and demand.

## *9.9 Enforcement Agencies in NYS*

1. The commissioner's designee having jurisdiction, county and city commissioners of health and local housing code enforcement agencies designated by the commissioner's designee having jurisdiction, or county or city commissioner of health shall have the same authority, powers, and duties within their respective jurisdictions as has the commissioner under the provisions of this title.
2. The commissioner or his/her representative and an official or agency specified in subdivision one of this section may request and shall receive from all public officers, departments, and agencies of the state and its political subdivisions such cooperation and assistance as may be necessary or proper in the enforcement of the provisions of this title.
3. Nothing contained in this title shall be construed to alter or abridge any duties and powers now or hereafter existing in the commissioner, county boards of health, city and county commissioners of health, the New York City department of housing preservation and development, and the department of health, local boards of health or other public agencies or public officials, or any private party.

## 9.10 Sale of Consumer Products Containing Lead or Cadmium in NYS

1. In the absence of a federal standard for a specific type of product, the commissioner shall establish the maximum quantity of lead or cadmium (and the manner of testing therefor) which may be released from glazed ceramic tableware, crystal, china, and other consumer products. Such maximum quantity shall be based on the best available scientific data and shall insure the safety of the public by reducing its exposure to lead and cadmium to the lowest practicable level. The commissioner may amend such maximum quantity (and the manner of testing therefor) where necessary or appropriate for the safety of the public. Until such maximum quantity of lead or cadmium established by the commissioner is effective, no glazed ceramic tableware shall be offered for sale which releases lead in excess of 7 parts per million or cadmium in excess of 0.5 parts per million.
2. The commissioner is empowered to order the recall of or confiscation of glazed ceramic tableware, crystal, china, or other consumer products offered for sale which do not meet the standards set forth in or pursuant to this section.
3. The commissioner of health may waive the provisions of this section in whole or in part upon a finding by the commissioner in a particular instance that there is no significant threat to the public health; with respect to miniatures the commissioner shall do so, on terms and conditions he or she shall establish, upon a final judicial or administrative finding that there is no immediate public health threat in that instance.

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