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CHILDHOOD LEAD POISONING PREVENTION:
A PROGRAM PLAN FOR GALVESTON COUNTY

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CHILDHOOD LEAD POISONING PREVENTION:
A PROGRAM PLAN FOR GALVESTON COUNTY

by

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Capstone

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Dedication

To Cindy, Angie, Erin, Eva, Dave, Josh, Talia, Panida,
Tom, June, George, and Margaret,
for being the best family in the world.

CHILDHOOD LEAD POISONING PREVENTION:
A PROGRAM PLAN FOR GALVESTON COUNTY

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Childhood lead poisoning continues to cause permanent brain damage and other serious sequelae throughout the United States. Although the prevalence is decreasing nationwide, Galveston County lags considerably behind most sections of the country. In 2003, the United States prevalence of lead poisoning in children under 6 years old had dropped to 1.93%, while Galveston County remained at 11.5% and its largest city, Galveston, was still 17.8%. Recent loss of grant funding further challenged Galveston County Health District's efforts to address this crisis.

Nationwide evaluations of childhood lead poisoning prevention programs have identified state-of-the-art programmatic elements consistently producing positive outcomes. From this data, recommendations have been developed to guide local programs. In this capstone, these guidelines are applied to evaluate Galveston County Health District's Childhood Lead Poisoning Prevention Program. A robust plan will then be provided to optimize program effectiveness and minimize this threat to the children of Galveston County.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Lead Poisoning Significance

Lead poisoning causes permanent brain damage, seizures and death (Randall, 1996), affects over 310,000 U.S. children under 6 years of age (CDC, 2006), and carries such a high cost to society that estimated savings from current recommendations could reach 19 billion dollars within the 1st year of implementation (HUD, 2004). Childhood lead poisoning has seen rapidly decreasing prevalence nationwide, although Galveston County lags considerably behind most sections of the U.S. In 2003, the national prevalence of lead poisoning in children under 6 years of age had dropped to 1.93% (CDC, n.d.b), while Galveston County from 2001-2003 remained high at 11.5% and its largest city, Galveston, was still 17.8% (Figure 1; Galveston County Health District [GCHD], 2004).

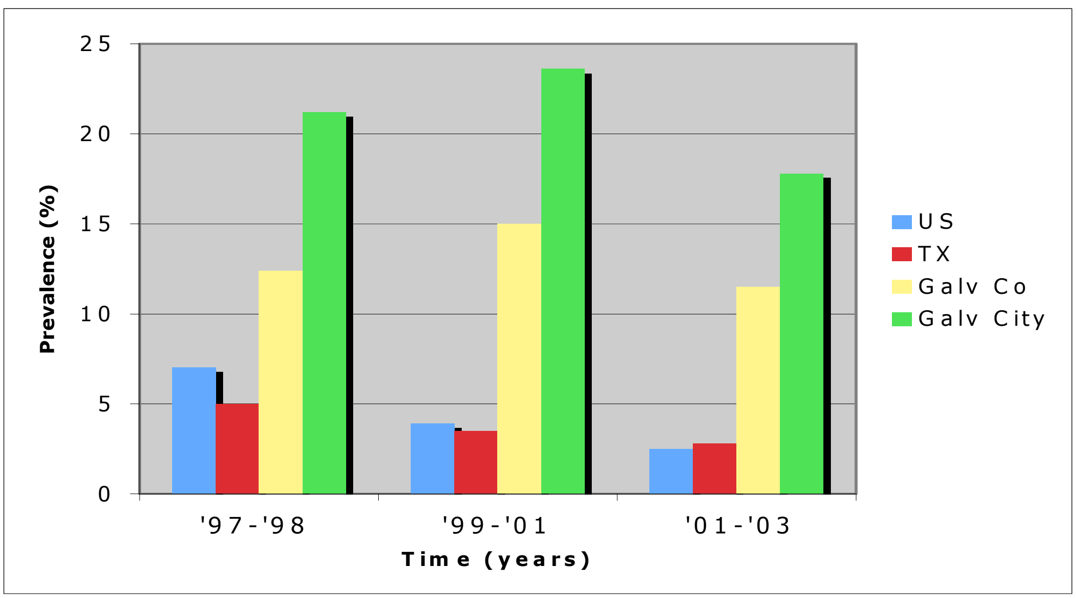

Figure 1. Prevalence of Elevated Blood Lead Levels >10mcg/dl in children <6 years old by Region (CDC, n.d.b; GCHD, 2000, 2003 & 2004).

Annual data from the Galveston Children's Report Card for 2004 (GCHD, University of Texas Medical Branch [UTMB] & Galveston Independent School District [GISD]) is presented in Figure 2 and provides more granularity but delivers the same message: Childhood lead poisoning prevalence in Galveston County, and especially the City of Galveston, remains considerably higher than the State of Texas. Furthermore, data from Figures 1 and 2 suggest improvements are not keeping pace with Texas or the nation.

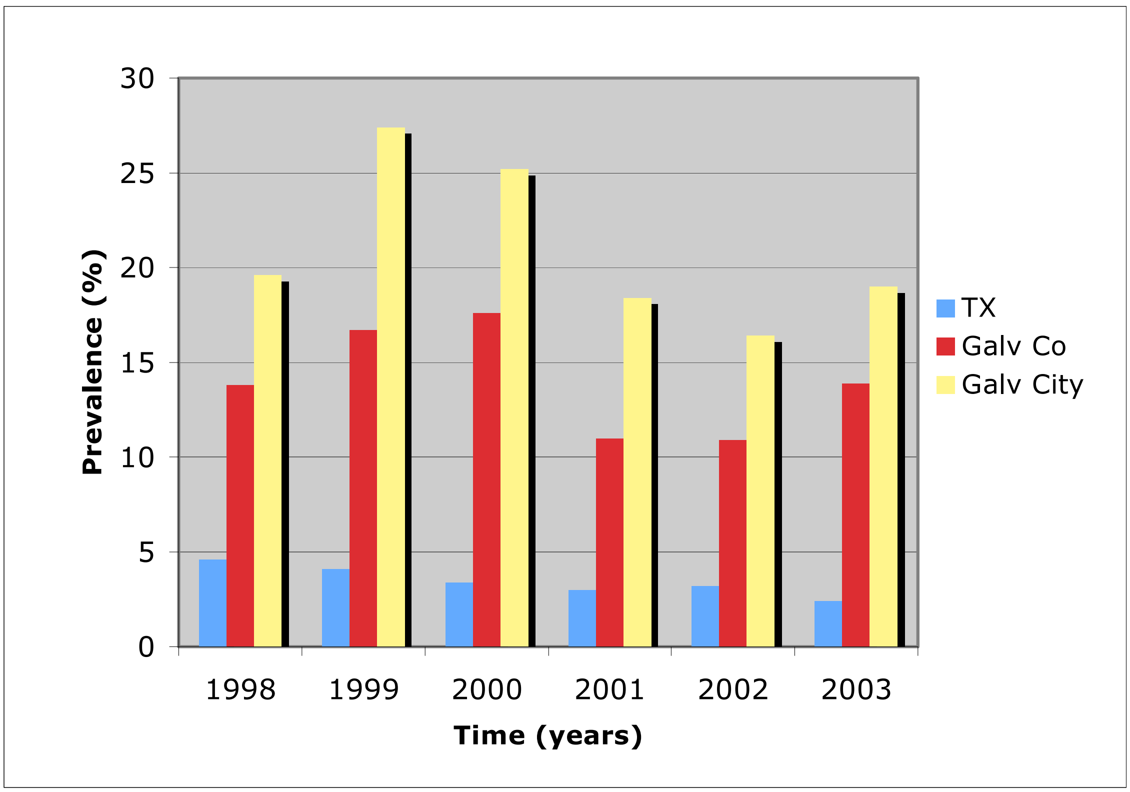

Figure 2. Comparative annual EBLL (>10mcg/dl) prevalence in children <6 years old by Region (adapted from GCHD, UTMB & GISD, 2004).

Motivation to Pursue Childhood Lead Poisoning Prevention

In addition to the enormous challenge faced by Galveston County, motivation to pursue this capstone topic also arose from preliminary literature revealing even more local threats. There remains a high density of older lead-based paint homes in Galveston County and barriers to mitigation, such as the historic designation of older homes that impedes abatement efforts (GCHD, 2004; W. J. Hamilton, personal communication, September 28, 2006; B. Reyes, personal communication, September 28, 2006; D. Wiltz-Beckham, personal communication, December 4, 2006). Effective action has been further impaired by the recent expiration of a Texas Department of State Health Services (TDSHS) grant, which provided critical infrastructure to the GCHD Childhood Lead Poisoning Prevention Program (D. Wiltz-Beckham, personal communication, December 4, 2006). Finally, Dana Wiltz-Beckham, D.V.M., Chief Epidemiologist at GCHD, included childhood lead poisoning prevention on a list of GCHD issues that would greatly benefit from graduate student involvement. Dr. Wiltz-Beckham has been exceptionally supportive throughout the development of this project.

Target Audience

The primary target audience is GCHD leadership and staff. The research and development is done in coordination with GCHD to ensure that a realistic goal is achieved--something with substantial benefit to the local effort. Indirectly, the children of Galveston County are the real target audience, with the expressed purpose of maximizing their potential for health and minimizing their environmental hazard risks.

Aim 1

Aim 1 for this paper is to provide a programmatic evaluation of GHCD's Childhood Lead Poisoning Prevention Program. Stated another way, the primary research question is: "What is the optimal approach to childhood lead poisoning prevention for GCHD?" It follows that the problem of interest is lead poisoning in children, specifically, the children of Galveston County. This section will assess elements and processes against published standards (Alliance for Healthy Housing [AHH], n.d.; National Center for Lead-Safe Housing [NCLSH], 1997, 1999, 2001).

Issues assessed include staffing, coordination between agencies, screening, case management and environmental investigations.

Aim 2

Aim 2 is to provide an optimal Childhood Lead Poisoning Prevention Plan for GCHD. This evidence-based plan will be drawn from previously referenced literature (AHH, n.d.; NCLSH, 1997, 1999, 2001) detailing current national recommendations for programs designed to address lead poisoning prevention in children.

Secondary Objectives

Secondary objectives include a brief review of specific local challenges and barriers to lead hazard control, with evidence-based recommendations drawn from best practices, such as the U.S. Department of Housing and Urban Development's (HUD) *Success Stories*, and lessons learned from large federal programmatic reviews (AHH, n.d.; HUD, 2002).

The intent is to leave GCHD with a robust program plan, which can be used to support grant or maintenance funding requests that will successfully address the extraordinary childhood lead toxicity problem facing Galveston County. The ultimate goal: To optimize program effectiveness and minimize this threat to the children who will soon become either productive or dependent citizens, depending on how well we protect them now.

LEAD: ELEMENT TO INTERVENTION

A more complete appreciation of disturbing local trends accompanies a broader understanding of the environmental hazard and its effects in the human body. This section provides background information pertaining to lead properties, usage, environmental sources, human absorption and physiology, toxicity symptoms, screening, and finally, a summary justification for public health focused intervention.

Lead Properties

Lead is a soft silvery-white (Stevens, 2000) or bluish-gray (CDC, 2005a) metallic element with the atomic symbol Pb (from the Latin *plumbum* [Lewis, 1985]) and atomic number 82 (Stevens, 2000). It is a naturally occurring, relatively uncommon metal in the earth's crust, rarely found in its elemental state, but more often in its +2 oxidation state, combined in various ores such as galena (PbS), anglesite ($PbSO_4$), and cerussite ($PbCO_3$). An estimated one third of the world's reserves of lead are located in North America (CDC, 2005a). The relatively low melting point, at 327.4° C (621.3° F; CDC, 2005a), renders this easily malleable metal susceptible to melting in a campfire (Grout, 2007). Lead conducts electricity poorly and its stable isotopes are all end products of radioactive decay of uranium and other heavy elements (Stevens, 2000). Resistance to corrosion is evident as metallic lead forms a thin film of lead compounds on exposure to air or water, protecting the metal from further oxidation (CDC, 2005a). These special properties determine the widespread usefulness of this popular metal.

Lead Uses

World History

Historically, this versatile metal has been called "the father of all metals, but the deity…associated with the substance was Saturn, the ghoulish titan who devoured his own young (Lewis, 1985, p. 1)." Colorful lead compounds provided pigments for cosmetics and paints, while recognized toxicity symptoms earned victims the "crazy as a painter" label (Lewis, 1985, p. 1). Acknowledging the adverse fertility effect (see absorption and physiology section below) a 2nd century Greek obstetrician (Stevens, 2000), Soranus, in *Gynecology*, recommended the mouth of the uterus be smeared with white lead to prevent contraception (Grout, 2007). Readily malleable, inexpensive, and resistant to corrosion, lead was an excellent choice for fashioning pitchers, cups, pots, pans, chastity belts, lead coins, debased bronze or brass coins, and counterfeit silver and gold coins. In the Middle Ages, alchemists sought to generate gold from lead and Gutenberg, in the late 15th century, used leaded type to open the way for mass printing, eradication of ignorance, and the ages of Reformation and Enlightenment. More sinister uses took advantage of this invisible, gradual-onset poison in Renaissance Europe, where "inconvenient relatives" were eliminated by the "world-weary French [who] referred to the metal as *poudre de la succession* – or succession powder (Lewis, 1985, p. 1)." Progressively increasing use in the production of pistols, rifles, cannons (Lewis, 1985), bullets, shot, and sinkers (CDC, 2005a) was observed and to some extent continues today. Value in plumbing has been demonstrated by extensive implementation throughout ancient Rome, where exemplary durability leaves some of those pipes still usable (Stevens, 2000). Today some authorities believe the use of lead plumbing poisoned the water, leading to widespread *plumbism* (lead toxicity syndrome) that was a primary contributor to the fall of the Roman Empire. Others believe that lead poisoning was not related to the fall, or that the etiology of plumbism was associated with lead-laden sauces and other food additives ingested by the Roman aristocracy. An excellent review by Grout presents various sides of the debate with considerable detail and full references. There is agreement, however, that the sweet taste and biological activity were instrumental in the use of lead compounds as popular condiments for seasoning food and stopping the fermentation process or disguising the taste of inferior wines (Lewis, 1985).

U.S. History

In the U.S., lead usage began almost on arrival of the first colonists, with forges and mines in Virginia by 1621. By the 20th century, as world leader in the production of refined lead, the U.S. also led in its consumption, using 1.3 million tons of lead in 1980, about 40% of the world's supply. Notable modern uses of lead include white lead (lead carbonate) in domestic house paint and leaded gasoline for motor vehicles. Although both were banned in the U.S., in 1978 and 1996, respectively, their ubiquitous use left an environment laden with lead that will continue to threaten health for generations (see environmental sources of lead below; CDC, 2005a). Lead carbonate is a white pigment that added durability to house paint, which contained up to 50% lead before 1955. Leaded paint is still used for industrial, military, and non-residential purposes (Gracia & Snodgrass, 2007). In the 1920's search for an anti-knock, performance-boosting gasoline additive, tetraethyl lead was the undisputed winner. While the 1921 discovery paved the way for the Ethyl corporation, a General Motors subsidiary, to virtually save the budding automotive industry, a dark side of this success story was quickly apparent. There is little doubt that the alkyl lead compound was a major contributor to "development of the high-power, high-compression internal combustion engines that were to win World War II and dominate the U.S. automotive industry until the early 1970's (Lewis, 1985, p. 3)." One of tetraethyl lead's developers, Thomas Midgeley, was the first of many to be stricken with a "mysterious illness" after exposure to this potent toxin (see symptoms of lead poisoning below; Lewis, 1985, p. 3). Although tetraethyl lead is still used for off-road vehicles and airplanes (CDC, 2005a), the predominant use of lead in the U.S. today involves storage batteries for automobiles, with ammunition being the largest non-battery use. Now that an overview of past and present uses for lead has been established, sources associated with human toxicity are more readily apparent.

Environmental Sources of Lead Toxicity

Lead has always occurred naturally, but in small amounts and low concentrations, until human activities altered that balance, increasing environmental levels more than 1,000-fold in the past three centuries. The greatest increase, between 1950 and 2000, is ascribed to the burgeoning use of leaded gasoline worldwide (CDC, 2005a). Mining, a "primary" source of lead, takes place mostly in Alaska and Missouri, but represents a small portion of the lead used by industry. Most lead is now derived from "secondary" sources, such as the recycling of lead-acid batteries. Up to 97% of these storage batteries are recycled (CDC, 2005a). Since many lead-containing substances present as sources in more than one exposure category, e.g., air and soil, this review of lead hazard exposure sources will be organized by exposure categories.

Air

The Environmental Protection Agency (EPA) reports atmospheric emissions of lead have decreased by 93% from 1982 to 2002, as the phase-out on leaded gasoline took effect. Current airborne threats include mines, smelters, and continued use of leaded gasoline in agricultural areas and other countries. While small particles of lead may travel considerable distances, and even be picked up from the soil, eventually lead becomes deposited onto land or surface water. One recent event involving lead-bearing soil reclamation to avoid potential carriage by wind, took place in Diamond Head Crater, Hawaii. Hawaii is the most militarized zone in the U.S., with eight major military bases, including a firing range in Diamond Head Crater (Environment News Service [ENS], 2004). Ammunition-related accumulation of lead in the soil prompted Major General Lee to announce on January 26, 2007, that the Hawaii Army National Guard's Environmental Office will coordinate a project to process approximately 20,000 tons of soil (Lee, 2007), with operations beginning early January, 2007, and expected completion by early May, 2007. Other sources of airborne lead may include drift from the restoration of homes and removal of lead-based paint from structures such as bridges or ships. Still more sources might include releases from industries involved in iron and steel production, lead-acid-battery manufacturing, non-ferrous (brass and bronze) foundries, volcanoes and cigarette

Figure 3. Diamond Head Crater soil reclamation project (ENS, 2004).

smoke (CDC, 2005a).

Soil

Lead adheres tenaciously to surface soil particles, so deposition from decades of automobile exhaust along highways, lead-based paint debris from sanded or scraped houses, and lead-arsenic pesticides from pre-World War II orchard use accumulate without natural clearance mechanisms. In essence, any method placing lead in the air, leads to deposition in soil (CDC, 2005a). Naturally occurring soil concentrations are <50 ppm lead. Many urban areas have >200 ppm and the EPA defines soil as a lead hazard with 400 ppm in a play area or 1200 ppm elsewhere in the yard. These values are non-enforceable, for guidance only. A blood lead level rise of 3 to 7 mcg/dl in children has been associated with every 1000 ppm rise in environmental soil or dust concentration, according to Lanphear, et al. (as cited in Gracia & Snodgrass, 2007).

Dust

House dust may originate from deteriorated or disturbed paint within the home, or be tracked in from outside. Household lead dust, with its sweet taste, is easily picked by small children whose hands are often in contact with the floor and their mouths. This is considered one of the primary means for lead ingestion in small children. Wipe sampling of house dust defines a lead hazard when a threshold of 40 mcg/ft^2 is exceeded, but significant elevations of blood lead levels have been associated with samples as low as 10 mcg/ft^2. Window sill samples must exceed "250 mcg/ft^2 to be considered hazardous due to the enhanced proportion of dust collection on a horizontal surface." (Gracia & Snodgrass, 2007)

Water

In water, lead is invisible, tasteless, and cannot be smelled. Surface and ground water lead levels are naturally very low. Contamination primarily occurs from lead leaching out of pipes, lead-soldered fittings, and brass faucets. Acidic or hot water will dissolve more lead from these sources. Since the use of lead-based products in household plumbing was banned in 1988, this is mainly an issue for homes built prior to that time (Gracia & Snodgrass, 2007). However, as pipes age, mineral deposits form a coating inside the pipes that insulate the water from the lead or solder, reducing the likelihood that lead will be released into the water (CDC, 2005a). Flushing the lines and using cold water may minimize exposure (Gracia & Snodgrass, 2007).

Food

When lead solder was discontinued, the amount of lead in canned food dropped 87% between 1980 and 1988. Small amounts of lead may still be found from lead dust on leafy fresh vegetables, which should be well rinsed before consumption. Glazed pottery, ceramic dishes, and leaded-crystal glassware may also contribute some lead to food. Whiskey made in radiators and other lead-containing apparatus may contain the toxin and soldered cans from other countries may still contain lead (CDC, 2005a).

Work

Adult lead poisoning is most commonly associated with occupational and recreational exposures. Workplace exposures place 0.5 to 1.5 million workers at risk (Gracia & Snodgrass, 2007). Ship-breaking, metal welders, and lead smelter workers are at highest risk, although battery manufacturing (Randall, 1996) and many other industrial and recreational activities involve significant lead exposure (Gracia & Snodgrass, 2007). See Table 1 for a listing of occupations with lead exposure risk and Table 2 for a listing of hobbies associated with increased lead hazard potential.

Table 1.

Occupations with Lead Exposure Risk

Manufacturing:	Construction
Bullets	Mining
Ceramics	Painting
Ceramic tiles	Radiator repair
Electrical components	Recovery of gold and silver
Lead batteries	Repair and reclamation of lead
Pottery	Smelting
Stained glass	Welding
Cable splicing	Work on firing ranges

Note. Adapted from CDC, n.d.c.

Table 2

Hobby Activities Associated with Elevated Lead Exposure Risk

Automotive repair	Pottery
Burning lead-painted wood	Refinishing furniture
Chemical preparation	Re-loading bullets
Firing range	Stained glass with lead solder
House construction or repair	Valve & pipe fittings
Making fishing weights	Welding

Note. Adapted from Randall, 1996.

Other Sources

Imported foods, cosmetics, folk remedies, and other products have been found to contain sufficient lead to warrant avoidance (Gracia & Snodgrass, 2007). Table 3 illustrates some unusual sources of environmental lead exposure.

Table 3.

Unusual Lead Hazard Sources

Mexican folk remedies	Imported spices
Greta[a]	Swanuri marili
Azarcon[b]	Kharchos suneli[d]
Alarcon[c]	Kozhambu
Alarzon[c,g]	Non-food ingestions
Coral[c]	Lead glazed ceramics
Liga[c]	Fishing weights
Maria Luisa[c]	Pool cue (yellow[e])
Rueda[c]	BBs[e]
Asian folk remedies	Gunshot wounds[e]
Paylooah	Surmaor Kohl[e,f]
Chuifong	Breathing smoke from burning
Tokuwan	wood & lead paint[e]
Ghasard	Chewing magazines or
Bali Goli	newspapers with lead ink[e]
Kandu	Chewing crayons containing
Chinese herbal tea	lead[e]
Hai Ge Fen	

Note. Adapted from Gracia & Snodgrass (2007) and Randall (1996).

[a]Yellow powder, 90% lead, any amount poisonous to children and adults (Randall, 1996). [b]Orange powder, 90% lead, given for intestinal illness, any amount poisonous to children & adults (Randall, 1996). [c]Alias for Azarcon (Randall, 1996). [d]Alias for Zafron (Randall, 1996). [e]Randall. [f]Arab powder used for eye make-up, applied to skin infections, and navel of newborn child (Randall, 1996).

Galveston County Sources

Primary sources of lead exposure in Galveston County include leaded paint on older homes, contaminated soil from the paint, residual soil contamination along highways from vehicle exhaust deposited during the leaded-gas era, local battery manufacturing, leaded paint still in use for parking lot stripes, roadways, marine and industrial purposes, hobbies involving stained glass with leaded came and solder, homemade fishing weights and ammunition re-loading (GCHD, 2004; D. Luna, personal communication, March 2, 2007; R. Schultz, personal communication, March 2, 2007).

Human Absorption and Physiology of Lead

Absorption of Lead

Absorption of lead typically involves three potential routes of exposure, *topical*, *inhalation*, and *ingestion*. The most common route of toxic exposure in adults involves inhalation, in contrast to the typical ingestion route for children (Gracia & Snodgrass, 2007). Topical exposures are usually insignificant since lead penetrates skin poorly unless carried in a vehicle like leaded gasoline, therefore this mode is not usually an issue for the general public, though it may be a problem for some occupational exposures. Damaged skin (e.g., abrasions, burns, lacerations) may increase skin absorption potential. On the hands, skin represents a convenient fomite for accidental lead ingestion when eating, drinking, smoking, or applying cosmetics (e.g., lip balm; CDC, 2005a). While most inhaled lead is directly absorbed, assimilation by ingestion is affected by many factors (Gracia & Snodgrass, 2007). Overall, adults absorb about 20% of ingested lead (Gracia & Snodgrass, 2007), with ingested absorption ranging from 6% postprandial to about 70% after one day of fasting (CDC, 2005a). Ziegler, Edwards, Jensen, Mahaffey, and Fomon (1978) demonstrated higher absorption and retention of ingested lead in children than previously reported for adults. Subsequently, children have been estimated to absorb 5 to 10 times more than adults (Gracia & Snodgrass, 2007), generally, felt to be about 50% of ingested lead (CDC, 2005a). The amount of absorption increases with deficiencies of iron, calcium, zinc, and ascorbic acid, to as much as 70% in malnourished children or pregnant women (Gracia & Snodgrass, 2007). Absorption from any route leads to storage, increasing the total body burden of lead.

What then, is the normal human blood lead level, when not affected by industrial lead exposure? Attempting to determine the baseline, pre-industrial body burden of lead, Grandjean, Nielson, and Shapiro (1979) examined dentine and dry cortical bone from Nubians who lived 5000 years ago. Similarly, Ericson, Shirahata, and Patterson (1979) assessed bones of Peruvians buried 1600 years ago and Patterson, Ericson, Manea-Krichten, and Shirahata (1991) determined lead concentrations in tooth enamel, femur, and rib from two populations: Southwest American Indians who lived 1000 years ago and subjects who lived 700 years ago in a desert tributary of the Colorado River. After correcting for diagenetic additions of lead from soil moisture, their findings suggest that mean skeletal lead levels in adult Americans today are 500-1000 times higher than pre-industrial levels. Patterson et al. concluded the probable existence of dysfunctions in most Americans from poisoning due to chronic, excessive overexposure to industrial lead. Ericson et al. suggest "natural interactions of lead in human cells have not yet been determined because reagents, nutrients and controls used in laboratory and field studies have been contaminated with lead far in excess of naturally occurring levels (p. 946)." Flegal and Smith (1992) calculated that the upper limit of acceptable childhood blood lead level, 10 mcg/dl, would be more than 600-fold higher than natural blood lead concentrations of humans. Finally, Flegal and Smith conclude that criteria for safe body lead burdens should take into account natural pre-industrial human lead concentrations.

Physiology of Lead

Physiologically, we first acknowledge that lead is poisonous in all forms with no natural biological role yet identified (Bryson, 1996). Upon entry to the body, through one of the avenues described above, about 99% of blood lead is bound to erythrocytes (Bryson, 1996), with a serum half-life of 30 days (Gracia & Snodgrass, 2007). About 65% is excreted via urine and 35% in the bile according to Rabinowitz, Wetherill, Kopple

(1976) and Griffen, Coulston, and Wills (1975; as cited in Gracia & Snodgrass). Sweat and epidermal exfoliation (e.g., skin, hair, and nails) are additional routes of excretion (Ford, Delaney, Ling, & Erickson, 2001). Adults eliminate about 99% of assimilated lead within two weeks, while children loose only about 32% in their waste. From the blood stream, lead enters soft tissues, such as the liver, kidney, lungs, brain, spleen, muscles, and heart (CDC, 2005a), where it has a half-life of 40 days (Gracia & Snodgrass, 2007). Finally, long term storage in bones and teeth represent 94% of total body lead in adults and 73% in children, where it is incorporated into the bony matrix, similar to calcium, for decades (CDC, 2005a). Lead half-life in bones has been estimated to range from 3 years in trabecular to 30 years in cortical bone (Bryson, 1996). Bone lead can re-enter the blood and organs during times of stress or increased calcium turnover, like pregnancy, lactation, menopause, chronic disease, fractures/immobilization, or chelation therapy (CDC, 2005a; Gracia & Snodgrass, 2007). Infants are particularly sensitive to neurologic toxicity since lead freely crosses the placenta and the fetus has no blood-brain barrier (Ford et al., 2001). Baghurst et al. (1991) found significant placental membrane lead elevations in pregnancies ending with late fetal death or premature birth. Anttila et al. (1996) found evidence suggesting an association between occupational lead exposure and the risk of gliomas. The International Agency for Research on Cancer (2006) classifies lead in Class 2B (possibly carcinogenic), inorganic lead compounds in Class 2A (probably carcinogenic), and organic lead compounds in Class 3 (not classifiable). Primary actions in the body include binding with ligands such as sulfhydryl groups, which explain interference with enzyme activity and the presence of lead in hair and nails. Mitochondria are critical target organelles where lead binds to mitochondrial membranes and interferes with protein and nucleic acid synthesis. Among the specific interactions, lead substitutes for calcium as an intracellular messenger, alters calcium distribution in subcellular components, activates protein kinase C, binds more actively to calmodulin than calcium and inhibits sodium- and potassium-ATPase, leading to increased intracellular calcium levels. Ultimately, these changes impact neurotransmission and vascular tone (Ford et al., 2001), producing hallmark signs of slowed nerve conduction resulting in peripheral neuropathy (Gracia & Snodgrass, 2007). Three important heme synthesis enzymes are inhibited by lead: Delta-aminolevulinic acid, coproporphyrinogen, and ferrochetolase (Gracia & Snodgrass, 2007). Classic lead anemia includes microcytic or normocytic, hypochromic red blood cells with reticulocytosis that may be associated with low iron. With chronic lead poisoning, red blood survival is also decreased. Basophilic stippling can be found in lead-induced anemia as well as iron deficiency or toxicity from arsenic, benzene, thorium or certain cancers (Bryson, 1996). Hemolytic anemias can result from acute high-level exposures (Gracia & Snodgrass, 2007). Another acute effect of lead is proximal renal tubular dysfunction leading to aminoaciduria, glycosuria, and hyperphosphaturia. While these effects are reversible, chronic exposure can produce irreversible lead nephropathy, associated with saturnine gout. This is a form characterized by attacks less frequent than primary gout but with more severe renal disease. Another differentiating feature: Saturnine gout may affect premenopausal women, a demographic group that rarely develops primary gout (Gracia & Snodgrass, 2007). Fertility is affected in men by reduced libido, lower total sperm counts, increased proportion of abnormal sperm, and even total sterility (Bryson, 1996). Women may experience menstrual irregularities, higher rates of miscarriage, increased spontaneous abortions or stillbirth, and preterm labor (Bryson, 1996; Gracia & Snodgrass, 2007).

Symptoms of Lead Toxicity

World History

Historically, the connection between physical symptoms and lead poisoning is said to have its origin with the lead colic citation by Hippocrates, around 370 BC. Waldon (as cited in Grout, 2007) warns that while painful colic and constipation were mentioned in part eight of the third book of *Epidemics*, attributed to Hippocrates, there is no reference to lead or to lead workers. The earliest clear reference to lead poisoning, in the 2nd century BC, is cited in *Alexipharmaca* by Nicander, who tells of "…gleaming, deadly white lead whose fresh colour is like milk…" and describes "…dry retching, chills, delusions, and overwhelming fatigue (Grout, 2007, p. 4)." Lewis (1985, p. 2) brings colorful detail to the Roman lead experience: "Romans of yesteryear, like Americans of today, equated limited exposure to lead with limited risk." He pointed out that low-level daily exposure spared victims the "full horrors" of acute lead poisoning, but left them vulnerable to "death by slow poisoning of the greatest empire the world has ever known." Symptoms of lead poisoning were apparent in Rome by the 1st century, when sexual exploits of Julius Caesar failed to father more than one known child. His successor, Caesar Augustus, appeared to demonstrate total sterility and a relative disinterest in sex. Much lead flowed from the wine, plumbing, cooking utensils, and food condiments, which together have been associated with the epidemics of saturnine gout, sterility throughout the Roman aristocratic males, and the striking rates of infertility and stillbirth among the women. Even more disturbing symptoms involved the "mental incompetence that came to be synonymous with the Roman elite." After "such clearly degenerate emperors as Caligula…and Commodus…it is said that Nero wore a breastplate of lead…as he fiddled and sang while Rome burned." Among exposures supporting the existence of an association between lead ingestion and the suspicious mental aberrations, a palace fountain provided the last of the Flavian emperors, Domitian, with continuously flowing leaded wine (Lewis, 1985, p. 2). Lelia M. Coyne, PhD, a well-published author and speaker on the subject of lead poisoning prevention, from Lincoln, Nebraska, related on the February 24, 2007, Leadnet listserv, that Charlemagne, in 802, had soldiers beheaded for violations of an edict forbidding the spiking of wine with lead. It was thought this restriction, and its harsh consequences for disobedience, were related to an adverse impact of lead poisoning on the performance of men in uniform.

U.S. History

In 1904, an Australian physician, Dr. Lockhart Gibson (as cited in Rabin, 1989), determined that residential lead paint produced lead poisoning in children. In 1914, U.S. authors concluded that lead poisoning was not very common, but three years later this chorus changed. Dr. Kenneth Blackfan from Johns Hopkins Medical School suggested that "in all patients with convulsions in which the etiological factor is not clear, lead should be suspected." From there, the more physicians looked for lead poisoning, the more they found (Rabin, 1989, p. 1).

In 1923, the American lead poisoning alarm resounded a little louder, when Thomas Midgeley, one of the developers of the much acclaimed gasoline anti-knock additive, tetraethyl lead, became violently ill. By 1924, 15 deaths in New Jersey and Ohio were added to a growing list of workers experiencing mental and other toxicity symptoms. These concerns led the Surgeon General to suspend production and sales of leaded gasoline in 1925 until his expert panel could investigate. Dr. Alice Hamilton of Harvard University was the only environmental health visionary on a panel that concluded in June 1926 that the seven months allowed were insufficient to test the "very slow gestation of that toxicological syndrome (Lewis, 1985, p. 4)." With "no good grounds for prohibiting the use of ethyl gasoline (Lewis, 1985, p. 4)" the ban was lifted with the suggestion that proper regulations be instituted. The decades to follow included the Depression, total war, and a post-war boom that left little room for "proper regulations," until 1970, when the Environmental Protection Agency was formed. The EPA initiated a leaded gas phase-out plan in 1975, but real traction followed the introduction of catalytic converters. Since lead would foul the converters that new car models carried, their key component, and "the undoing of lead was that noblest of noble metals, platinum (Lewis, 1985, p. 4)." Dramatic reductions in environmental and blood lead levels have continued since that time, assisted by elimination of other sources such as leaded residential house paint, solder in food cans and plumbing. While influx of the toxic substance still declines, the environmental burden remains high and symptoms continue from the residual exposure.

Present day symptoms can be discussed in terms of acute versus chronic exposure, and categorized by the blood lead levels (BLL) associated with progressing levels of toxic severity.

The literature has much to say about the BLL chosen to trigger intervention. The most well known BLL criteria for initiating further action has been CDC's BLL of concern. This value has progressively decreased as adverse health effects became better known. From 1960 to 1991, the BLL for individual intervention dropped from 60 to 15 mcg/dl. A seminal study by Needleman et al. (1979) evaluated lead levels in deciduous teeth and found an association with neuropsychological deficits that may interfere with classroom performance. Needleman et al. suggested that non-adaptive behavior increased in a dose-response fashion to dentine lead levels at doses below those producing clinically diagnosable symptoms. From this landmark study, Bellinger et al. (1991), Baghurst et al. (1992), Canfield et al. (2003), and a re-analysis by Bellinger (2003) proceeded to clarify an association with reduced I.Q. at blood lead levels below 5 mcg/dl without an apparent threshold. These findings would support the statement by Patterson et al. (1991) that present-day toxicity is virtually universal, given the remarkable elevation of body lead concentrations compared to pre-industrial humans. Nevertheless, community-wide primary lead poisoning prevention activities continue to be recommended by the CDC for areas where many children have BLLs greater than the current level of concern, set at ≥10 mcg/dl (CDC, 2005b).

Table 4 is adapted from Gracia & Snodgrass (2007) and provides an overview of symptoms with corresponding BLLs for categories ranging from asymptomatic or impaired abilities (<10 mcg/dl) to severe acute toxicity (>100 mcg/dl).

BLL <10 mcg/dl has been increasingly recognized for subtle cognitive deficits with evidence suggesting that no actual threshold exists, as indicated in the discussion above. Lack of a fully developed blood brain barrier has been described for the increased susceptibility of younger children to the central nervous system (CNS) effects of lead, which appear to include abnormal brain cell differentiation called "pruning (Gracia & Snodgrass, 2007, p. 48)."

BLL >10 and <40 mcg/dl has been associated with neurobehavioral symptoms including impulsivity, distractibility, short attention span which may develop into antisocial behavioral behaviors. Chelation therapy has not been shown to reverse cognitive deficiencies at these lower BLLs (Rogan et al., 2001), hence the importance of primary prevention is still strongly emphasized (Rosen & Mushak, 2001). Gracia & Snodgrass cite multiple studies that have shown a 1-3 point IQ drop in association with an increase of BLL from 10 to 20 mcg/dl.

BLL >40 and <70 mcg/dl carries an increasing likelihood that overt symptoms may develop, including the most common, colic and constipation. CNS symptoms such as headache, agitation, and marked fatigue may progress to stupor and convulsions as the BLL rises. The most common reported occupational lead exposure effect is the classic peripheral neuropathy with forearm extensor weakness, producing wrist drop with normal sensation. This condition can be easily misdiagnosed as carpal tunnel syndrome (Gracia & Snodgrass, 2007).

BLL >70 mcg/dl in children and >100 mcg/dl in adults frequently presents with severe toxicity such as encephalopathy (Gracia & Snodgrass, 2007). Black tarry stools, nausea and vomiting, seizures, confusion, coma, and even death can result (Bryson, 1996).

The duration of cognitive deficits associated with lead poisoning was examined by White, Diamond, Proctor, Morey, and Hu (1993). Their study of adults with a documented history of lead poisoning before age 4 suggests that acute encephalopathy resolved into chronic subclinical encephalopathy, with associated cognitive dysfunction still evident 50 years later.

Table 4

Symptoms of Lead Toxicity

Level	Children	Adults
<10 mcg/dl	Decreased learning and memory	
	Decreased verbal ability	
	Impaired fine motor coordination	
	Signs of Attention Deficit Hyperactivity	
	Lower IQ	
	Impaired speech and hearing	
10 to 39 mcg/dl	Myalgia or paresthesia	
	Irritability	
	Mild fatigue, lethargy	
	Abdominal discomfort	
40 to 70 mcg/dl	Arthralgia	Fatigue
	Difficulty concentrating	Somnolence
	General fatigue	Moodiness
	Headache	Lessened leisure interest
	Muscular exhaustibility	Impaired psychometrics
	Tremor	Chronic hypertension effects
	Weight loss	Reproductive effects
	Vomiting	

	Constipation	
	Diffuse abdominal pain	
>70 mcg/dl	Lead lines (blue-black gum line)	Headache
	Colic (intermittent, severe cramps)	Memory loss
	Paresthesias or paralysis	Decreased libido
	Encephalopathy	Insomnia
		Metallic taste
		Abdominal pain
		Constipation
		Myalgias and arthralgias
		Nephropathy
>100 mcg/dl	Encephalopathy	Encephalopathy
	Seizures	Other CNS effects
	Anemia	Anemia
	Nephropathy	Nephropathy

Note. Adapted from Gracia & Snodgrass, 2007.

Screening for Childhood Lead Poisoning

Screening policies for any given community take into account authoritative current recommendations and specific local circumstances, such as available resources and risk factors. Nationwide, screening methodology to identify children with elevated blood lead levels (EBLLs) varies between states. Some have aggressive legislative support, like Rhode Island, where providers are required by law to draw annual BLLs on all children from 9 months to 6 years of age (discussed under Key Themes below; Rhode Island Department of Health, 2005). Most states are more like Texas, where recommendations mirror the CDC guidelines but no requirement to screen is statutory. Medicaid is an exception, providing a nationwide requirement that all beneficiaries receive BLL testing at 12 and 24 months of age, or between 36 and 72 months of age if a BLL was not done previously. Medicaid's position is described in reference to Phase 2 of NHANES III findings that 83% of children <6 years old with EBLL >20 mcg/dl are Medicaid enrollees and only 81% of Medicaid enrollees <6 years old have been screened (CDC, 2000). CDC guidance has not changed since 1997, but the CDC Advisory Committee on Childhood Lead Poisoning Prevention recommendations from 2002 (CDC, 2002) provide a clear statement regarding universal screening: Universal BLL screening is advised for children living in areas where ≥27% of homes were built before 1950 (City of Galveston = 33% [GCHD, 2004]) and where prevalence of EBLL in children aged 1 and 2 years old is ≥12% (City of Galveston = 19% for <6 years old in 2003 [GCHD, UTMB, & GISD, 2004]). In addition to the prevalence of residential lead paint and overall EBLLs, other risk factors might include health disparities relative to EBLLs. Part 2 of NHANES III illustrates at least two disparities associated with poverty and racial or ethnic minority status among children <6 years old, living in houses built before 1946: (a) EBLL among low income children was 16.4% versus 0.9% among high income children, and (b) EBLL prevalence among non-Hispanic black children was 21.9%, Mexican-American children, 13.0%, and non-Hispanic white children, 5.6% (CDC, 2000). Table 5 provides population comparison data for the EBLL disparity groups to illustrate how Galveston County (2005 data) and the City of Galveston (2000 data) compare with Texas (2005 data) and U.S. (2005 data) according to demographic categories including percent of families living below the poverty level, race and ethnic compositions. In essence, the City of Galveston ranks highest for percent of families living in poverty (17.8%), and proportion of total population (any age) in the non-Hispanic black group, with the second highest rate for proportion of population in the Hispanic group (25.8%; U.S. Census Bureau, n.d.). This data shows that the City of Galveston maintains a high risk population for the prevalence of EBLLs, consistent with previously presented data showing, in fact, that the prevalence of EBLLs has perpetually remained higher in Galveston County, and in particular the City of Galveston than the prevalence of EBLLs for Texas and the nation.

Table 5

Population Demographic Comparisons by Region (%)

		Families in poverty	Hispanic	Non-Hispanic Black	Non-Hispanic White
United States	(2005)	10.2	14.5	12.1	74.7
Texas	(2005)	14.2	35.5	11.0	71.9
Galveston County	(2005)	10.1	20.1	14.5	75.8
Galveston City	(2000)[a]	17.8	25.8	25.5	58.7

Note. 2005 American Community Survey data was available for U.S., Texas, and Galveston County, but not for Galveston City; Census 2000 data used for Galveston City. (U.S. Census Bureau, n.d.).

Justification for Public Health Focus

The following literature review justifies a public health focus on childhood lead poisoning because this environmental hazard produces severe *health effects*, has a high *prevalence*, is *preventable*, and inflicts a large, long-term *cost to the community*. Additional literature review findings pertinent to the local Galveston community, those representing significant lead poisoning prevention issues, and key themes in the literature are included below.

Health Effects of Lead Toxicity

Health effects of lead toxicity, which include irreversible brain damage and death (Randall, 1996), are dose-related and categorized by the measurement of Elevated Blood Lead Levels (EBLL). There does not appear to be a threshold value. While historically it has been assumed that levels under 10 mcg/dl were safe, recent evidence suggests there is an association with reduced cognitive function, even at these low levels (CDC, 2005b). Over 10 mcg/dl, many adverse effects have been identified, including brain damage, decreased intelligence and slowed neurobehavioral development. Over 20 mcg/dl, the degree of brain damage is greater, ultimately leading to seizures, coma and death (Randall).

Prevalence of Lead Poisoning

Prevalence is declining overall, but lead toxicity still affects over 310,000 U.S. children under 6 years of age (CDC, 2006) and in 2003 83% of all U.S. homes built before 1978 still contained some lead-based paint (Utah Department of Health, 2003). Also in 2003, the national prevalence of childhood EBLL (under 6 years old) was 1.93% (CDC, n.d.b), compared with the 2003 prevalence of 2.4% for Texas, 13.9% for Galveston County and 19.0% for Galveston, its largest city (GCHD, UTMB, & GISD, 2004).

Prevention Potential

Preventability of this public health problem via systematic interventions has been demonstrated by numerous examples (AHH, n.d.; CDC, n.d.b; NCLSH, 1997, 1999, 2001; Rhode Island Department of Health, 2005; HUD, 2002, 2004). Programs identifying and ameliorating the primary source of lead toxicity, residential lead-based paint, have shown substantial impact (AHH, n.d.; CDC, n.d.b; NCLSH, 1997, 1999, 2001; Rhode Island Department of Health, 2005; HUD, 2002, 2004). Rhode Island EBLL prevalence in children under 6 years of age fell over the past decade from 20% to 5% with a combination of statutory requirements and programmatic action (Rhode Island Department of Health, 2005). Many such success stories have been identified and serve as the basis for the direction of this paper (AHH, n.d.; HUD, 2002).

Community Impact

Cost to the community was estimated in 1999 by HUD's Regulatory Impact Analysis (HUD, 2004). In an exhaustive effort to determine the fiscal effects of lead based paint elimination from pre-1973 homes, the largest benefit involved 1 and 2 year old children. The community impact of lead poisoning prevention over the lifetime of this 2-year cohort exceeded 19 billion dollars within the first year of rule implementation.

Pertinent Literature Findings

Further literature review findings included GCHD grant applications to the Texas Department of Health and the Environmental Protection Agency, which provided baseline data from which to establish initial comparisons of Galveston County to other U.S. locations (GCHD, 2000, 2003). HUD websites were rich with data regarding grant opportunities, a listing of grantees and especially grantee *Success Stories* of particularly effective grant-related efforts (HUD, 2002, 2006a, 2006b). HUD's *Final Report (2004)* contains a comprehensive, retrospective observational study examining data from over 3,000 houses, distributed across the U.S. Detailed descriptions of interventions are given, along with outcome indicators including dust lead levels and occupant blood lead levels before and after the interventions. This review concluded that all strategies were highly effective and offered a compendium of different parameters, such as intervention costs, to assist prospective users in determining optimal directions for their efforts (HUD, 2004). The National Center for Lead-Safe Housing's Lessons Learned publication from 1997 was especially helpful for insights regarding historic preservation issues, a particularly challenging problem for Galveston County. Regional expertise from Brenda Reyes, M.D., MPH, Bureau Chief, Children's Environmental Health, Houston Department of Health and Human Services, and Winifred J. Hamilton, Ph.D., S.M., Assistant Professor, Departments of Medicine and Neurosurgery, Director, Environmental Health Section, Chronic Disease Prevention and Control Research, Baylor College of Medicine, Houston, Texas, were especially helpful in the clarification of local lead poisoning prevention programs and the identification of fruitful resources, such as Leadnet. Leadnet is an internet-based discussion group for lead poisoning prevention advocates. Research questions posed in this forum of highly knowledgeable and motivated individuals identified some outstanding programmatic achievements and resources. One such discovery via Leadnet query was The National Center for Healthy Housing's "evaluation in a box," intended for enabling grantees to evaluate their own programs (R. L. Morley, personal communication, October 26, November 21, 2006). Another valuable find involved a HUD product that addressed the adverse lead poisoning prevention impact of historic site designation on lead abatement in older homes (HUD, 1995).

To understand the HUD product, it is necessary to know two primary problems resulting from historic site designation of lead-based older homes. First, tightly regulated abatement guidelines drive costs above what most homeowners can afford. Second, when government funds, such as HUD Lead Hazard Control Grants or matching block grant funds, are involved, additional requirements are included. While fund-related stipulations properly ensure that government investments are used for the intended purpose and protected, the expenses and long term commitments commensurate with use of these funds can effectively render projects impractical (B. Reyes, personal communication, September 28, 2006). In response to this dilemma, HUD developed the *Prototype Programmatic Agreement among State Historical Preservation Office and the Advisory Council on Historic Preservation and the Lead-Based Paint Hazard Control Grant Recipient* (HUD, 1995). This template facilitates cooperation between state agencies and paves the way to enable lead hazard mitigation of these homes. A similar memorandum of agreement between the Texas Historical Preservation Office and the Texas Department of State Health Services or possibly GCHD might be an effective tool to overcome one of the major local barriers to lead hazard control. Among the success stories identified to date, Burlington, Vermont, overcame this challenge by forming an agreement between the Vermont State Historical Preservation Office and the Vermont Housing Conservation Board (HUD, 2002). Similarly, the City of Stamford, Connecticut, "united the goals of lead hazard reduction and historic preservation (HUD, 2002, p. 2)." Other *Success Stories* (HUD) describe novel approaches to the stabilization of funding for lead poisoning prevention programs and specific interventions that have succeeded against barriers similar to those currently faced in Galveston County.

Key Themes in the Literature

Key themes from the research thus far would include the striking impact of statutory requirements on the success of EBLL screening. For example, according to CDC surveillance data, Texas Department of Health *recommendations* for blood lead level screening result in 13% of all children under 6 years old being tested in 2003 (CDC, n.d.b). In contrast, Rhode Island's *mandate* by-law that providers screen children annually from 9 months to 6 years of age achieved a 43% screening rate by 6 years of age in 2003 (CDC, n.d.b). These states independently publish even more impressive differences. In 2002, Texas Childhood Lead Poisoning Prevention Program (Randall, 1996) reported 6% of Texas children were tested by 15 years of age, while 75% of Rhode Island children were tested by 18 months of age in 2001, according to the Rhode Island Childhood Lead Poisoning Prevention Program's *The Numbers 2005 Edition* (Rhode Island Department of Health, 2005). Another theme, the statutory variation in lead hazard mitigation, also seems to contribute substantially to the achievement of outcome goals. Again, the State of Rhode Island requires landlord compliance with enhanced state mitigation laws when a lead hazard is identified. This requirement remains regardless of historic preservation designation (State of Rhode Island Housing Resources Commission, 2005). Overall, Rhode Island has seen the prevalence of EBLL in children under 6 years old drop from 20% to under 5% in the past decade (Rhode Island Department of Health, 2005). Historic site designation of older lead-based paint homes has already been discussed, but was another prominent theme in the literature (AHH, n.d.; HUD, 1995, 2002). One last theme worth mentioning here is the focus on "silver bullet" processes rather than robust total-program emphasis (AHH, n.d.; HUD, 2002). This strategy appears related to the presence of specific barriers that justify the type of novel approach needed to successfully compete for grant or other funding support. Requests to fund basic programmatic requirements may not compete as well for tight funding streams unless they can be tied to a high profile intervention (R. L. Morley, personal communication, October 26, and November 21, 2006; B. Reyes, personal communication, September 28, 2006).

RESEARCH PLAN

Project Significance

This project has substantial significance for Galveston County, and the broader context of lead poisoning prevention. As indicated above, Galveston County, and especially the City of Galveston, has childhood lead poisoning prevalence rates higher than most of the nation and little or no significant improvement trend over the past several years. Minimal infrastructure to address this overwhelming need further magnifies a serious health hazard. This research is designed to gather critical information and prepare the program plan capable of responding definitively to the local childhood lead poisoning crisis. Funding will be needed to fully implement the entire program, hence elements ready for immediate implementation will be highlighted and funding opportunities for the remaining elements are provided. This project brings tremendous hope and potential for children and families to achieve long overdue relief from lead poisoning that continues to threaten Galveston County. Regarding the broader context, successful implementation of this research project product will significantly benefit other struggling programs, and those advising them, by offering another strong option on the list to consider in their search for a robust response to this oppressive problem.

Methods

Aim 1

Aim 1, a programmatic evaluation of GCHD's Childhood Lead Poisoning Prevention Program (CLPPP), compares current status with published standards. The project began with a retrospective, narrative review of the literature in conjunction with expert consultation. The initial goal was development of a programmatic evaluation tool (see Appendix), hereafter referred to as "the tool." Primary sources of information for the tool consisted of recommendations published by the National Center for Lead-Safe Housing (NCLSH). The NCLSH guidelines were presented along with the results of nationwide programmatic reviews (NCLSH, 1999, 2001) and lessons learned (NCLSH,

1997) that provided the evidence and justification for these recommendations. For the purpose of this project, the guidance adopted for the tool pertained to critical program issues such as staffing, coordination between agencies, screening, case management and environmental investigations. Application of the tool for programmatic evaluation at GCHD has met with enthusiastic support from GCHD staff, including Diana Luna, BSN, Community Health Nurse, Ronnie Schultz, Director, Environmental Health Programs, and Dr. Dana Wiltz-Beckham, Chief Epidemiologist. Once the evaluation comparing GCHD's CLPPP with these standards was completed, a narrative description of these findings was developed for the results section below and attention was directed to the completion of Aim 2.

Aim 2

Aim 2 involved the development of a programmatic plan based on information derived from Aim 1 that included current evidence-based recommendations in the literature. The plan for GCHD CLPPP was specifically designed to encompass staffing requirements, recommendations for interagency coordination, screening, case management, and environmental investigations. Secondary objectives were then addressed with inclusion of estimated annual program budget requirements and focused interventions drawn from best practice examples to approach specific local challenges or barriers to successful implementation. Ongoing coordination with GCHD staff ensured that the product addressed local needs to the greatest extent possible.

The long-term objective was to advance a package that GCHD could present to potential grant or maintenance funding sources to facilitate establishment of a robust program prepared to meet current needs and respond to challenges that will inevitably occur.

RESULTS

Aim 1

Results of the GCHD programmatic evaluation are provided in table and narrative formats. Table 6 presents parallel programmatic element comparisons between GCHD CLPPP and literature-based recommendations for screening, case management, environmental investigations, and major staffing requirements. The narrative description covers additional research findings with brief references to Table 6 contents, a discussion of additional staffing concerns, including workload projection and data integrity issues, funding considerations, and coordination between agencies, contractors and program staff. Recommendations appearing in Table 6 provided the basis for development of the proposed program plan in Aim 2 (NCLSH, 1997, 1999, 2001; Smith, 2006; Texas Department of State Health Services [TDSHS], 2004).

Table 6 demonstrates strengths and opportunities for enhancing the current GCHD CLPPP. Strengths include several continuity staff members with corporate memory, an exceptionally well-trained environmental investigator, responsive leadership, favorable personnel policies, and cooperative working relationships with the housing department and local contractors. Areas for improvement will require additional staff and funding before full realization, but include billing for case management services, billing for environmental investigations, the addition of a full-time program manager, full implementation of the STELLAR (CDC, n.d.a) medical and environmental case management tracking system, and more aggressive screening efforts to support Healthy People 2010 and TXCLPPP goals to eliminate childhood lead poisoning by the year 2010. STELLAR is a computer software application designed to facilitate tracking of medical and environmental activities related to lead poisoning cases. The acronym stands for *Systematic Tracking of Elevated Lead Levels & Remediation*. The tool is provided free of charge to State and local CLPPPs (CDC, n.d.a).

Table 6

Comparison of GCHD Programmatic Evaluation Results with Literature-based Recommendations[a,b,c]

Programmatic Element	GCHD CLPPP	Literature Recommendations
1. Screening		
All BLLs directly reported from labs to TXCLPPP?	Yes[d].	Direct reporting from labs for all BLLs to state CLPPP is recommended[a].
Effective system to identify new cases of childhood lead poisoning (EBLL ≥20mcg/dl)?	Qualified yes; from UTMB and 4Cs clinics, but not remainder of Galveston County[e].	Ability to identify new cases recommended[a].
Importance of routine screening emphasized?	Educational activities include about 20 health fairs per year[e].	When low penetration exists in high-risk areas, importance of screening needs continued emphasis[a].
Does TXCLPPP work with Medicaid to ensure beneficiary screening?	Not known at GCHD staff level. Identification of Medicaid eligible children not clearly defined. Screening plan = state recommendations[c].	State Medicaid should work with all CLPPPs to ensure high-risk children, including Medicaid beneficiaries, are screened[a].

2. Case Management (CM) System in place for CM initiation and tracking?	No written protocol known. Written records in various formats kept until closure, then filed. No spreadsheet or other formal tracking system used[f]. STELLAR is available at GCHD, but minimally used for data entry to TDSHS; does not fully utilize designed tracking capabilities[d].	System in place should identify and track all children receiving CM services[a].
Trigger to initiate CM services?	CM is provided for anyone referred from a variety of sources. No specific threshold BLL identified for CM initiation[f].	CM should be offered to all children w/EBLLs, as resources allow, but at a minimum, CM provided at BLLs recommended by the CDC[a].
Practice changes: Is follow-up capability for CM being evaluated?	Not known at GCHD staff level[f].	Recommended[a].
Is this information being used to advocate for needed resources?	Not known at GCHD staff level [f].	Recommended[a].

Is this information being used to advocate for policy changes to improve outcomes for children with EBLLs?	Not known at GCHD staff level [f].	Recommended[a].
Does TXCLPPP work with Medicaid to ensure reimbursement for CM services?	Not known at GCHD staff level[d,f].	States without Medicaid CM reimbursement should immediately secure such reimbursement[a].
Are CM services reimbursed by Medicaid?	No reimbursement for CM services known[d,f].	TDSHS reported Medicaid reimbursement for up to 5 visits with prior authorization[b]. Harris County, TX, reported CM billing rates of $54 per initial visit and $16 per follow-up (up to 6) in 2000[a]. Local programs not billing, but in states with reimbursement available, should immediately secure reimbursement. Costs associated with CM services should be tracked to ensure rates reflect actual costs of

		delivery[a].
3. Environmental Investigations (EI)		
Trigger to initiate EI:		
Provided for EBLL ≥20mcg/dl?	Yes[g].	Should be provided to all children with EBLL ≥20.
Provided for repeat EBLL between 15 and 19mcg/dl?	Upon request[g].	Should be provided to all children with repeat EBLL between 15 and 19mcg/dl[a].
Offered for EBLL ≥10mcg/dl?	No system in place to voluntarily offer EI for EBLL ≥10mcg/dl[g].	Should be offered, as resources allow[a].
Is lead dust testing part of routine EI protocol?	Yes[g].	Lead dust testing should be part of routine EI protocol[a].
Is there close-out criteria protocol including documented reduction in child's BLL or post intervention testing?	Report is sent to client upon completion, but no follow-up on child's BLL or post intervention testing included in protocol. Post intervention testing done upon request[g].	Close-out criteria should include reduction in child's BLL, control of environmental hazard, and provisions for administrative closure[a].
Practice changes:		

Is follow-up capability for EI being evaluated?	Not formally[g].	Recommended[a].
Is this information being used to advocate for needed resources?	Not known to staff[g].	Recommended[a].
Is this information being used to advocate for policy changes to improve outcomes for children with EBLLs?	Not known to staff[g].	Recommended[a].
Does TXCLPPP work with Medicaid to ensure reimbursement for EI services?	Not known to staff[g].	States without Medicaid EI reimbursement should immediately secure such reimbursement[a].
Are EI services reimbursed by Medicaid?	No reimbursement for EI services in Texas known, but aware that Medicaid does not cover lead dust testing[g].	In Texas, for 1999, EI funded by state general revenue funds[b], but no Medicaid reimbursement[a,b]. Where local programs are not billing, but are in states with Medicaid EI reimbursement available, should immediately secure reimbursement. Costs associated with EI

		services should be tracked to ensure rates reflect actual costs of delivery[a].
4. Staffing Composition and Requirements		
Program manager	Currently GCHD has no CLPPP staff. All CLPPP needs are additional duties for GCHD personnel. Until 2003, TDSHS grant supported this position, yielding more robust data management, screening and educational outreach efforts[d,e,f].	1 FTE dedicated to manage lead hazard control program. If permanent budget does not permit, consider temporary FTE until program established. Position critical to program success and requires solid administrative and managerial skills, flexibility, creative problem solving, and an ability to learn from others[c].
Community Health Nurse	Currently no designated CLPPP nurses, but 3 GCHD nurses participate in CM. Most active CM nurse estimates <1% of time currently needed to manage the approximately 6 referrals per year and projects adequate nursing manpower is present to	Specific recommendations not given since requirements vary according to program structure and many other local variables[c].

	absorb 2 to 3 fold increase in volume without additional nursing staff[f].	
Environmental Investigations	Presently at 0.05 FTE, could absorb a doubling of workload to 0.10 FTE, or more, even with new protocol inclusions. Availability of local contractors provide sufficient reserve at this time for near future projections. An important strength: Principal investigator maintains current state certification as a Lead Risk Assessor[g].	Program-unique variations in task allocation are sufficient that recommendations take the form of considerations to assist programs in determining location specific requirements, rather than overt FTE recommendations[c].

Note. 4Cs Clinic = County Coordinated Community Clinics. BLL = Blood lead level. EBLL = Elevated blood lead levels, defined as BLL ≥10mcg/dl. STELLAR = Systematic Tracking of Elevated Lead Levels And Remediation (CDC, n.d.a). TDSHS = Texas Department of State Health Services. TXCLPPP = Texas Department of State Health Services Childhood Lead Poisoning Prevention Program. UTMB = University of Texas Medical Branch.
[a]NCLSH, 2001. [b]NCLSH, 1999. [c]NCLSH, 1997. [d]D. Beckham and S. Cuellar, personal communication, March 15, 2007. [e]D. Beckham and D. Luna, personal communication, January 18, 2007. [f]D. Luna, personal communication, March 2, 2007. [g]R. Schultz, personal communication, March 2, 2007.

Additional Staffing Considerations

Staffing considerations not already covered in Table 6 involve number, specialty mix, and in-house versus contracted outside professionals. To determine staffing number, demand must be projected. Workload projections require an evaluation of data to assess demand for services. Data integrity issues are examined later in the Discussion section, but it is sufficient to mention here that CDC and GCHD EBLL prevalence data vary considerably. In an effort to determine workload and the impact of increased screening, clarification of the EBLL prevalence data issue revealed complexities exceeding the scope of this section or even this paper (D. Beckham and S. Cuellar, personal communication, March 15, 2007; T. Willis, personal communication, March 23, 2007). Summarizing those findings, the majority of BLLs sent from the GCHD 4Cs clinic to TDSHS did not include the designation *venous*. Although the full set of data was forwarded to the CDC, most of the elevated BLLs from 4Cs and UTMB were unacceptable for inclusion in the CDC Surveillance Data spreadsheet (CDC, n.d.b). CDC only enters EBLL results from venous samples, specifically eliminating capillary or unknown samples unless additional confirmatory tests are done according to guidelines. Consequently most EBLL values reported by GCHD are not included in the CDC web-based reporting. This is one of several reasons identified for the lower EBLL prevalence on the CDC website compared to GCHD. While it is easy to inform staff to add the source designation to samples submitted to TDSHS, the situation is not so simple. UTMB, the other primary source for GCHD data sent almost exclusively capillary samples to TDSHS, which were also inadmissible to the CDC database without EBLL confirmation test results. It takes manpower to stay abreast of changes, like the growing use of capillary samples, and to track the collateral impacts. The manning at GCHD is insufficient to accomplish even these most fundamental needs of keeping up with reporting requirements and sample processing. There is no way they can be expected to proactively engage in far more complicated tasks such as developing network alliances to open doors for increased screening, compliance with environmental lead reduction policies and funding streams critical to program viability.

Exhaustive efforts and much time are required to clean up inaccuracies that creep into a database and address the myriad of recommendations constantly flowing from national and state agencies for implementation at the county level. To meet these needs, sufficient designated manpower over time is critical, yet not adequately provided for GCHD's CLPPP. With the understandable impact of deficient program support on GCHD database integrity in better perspective, the daunting task of workload projections can be addressed.

Workload projection begins with demand, which, for BLL screening in Galveston County, means approximately 1000 to 2000 children under 6 years of age annually since 1997 (CDC, n.d.b; GCHD, 2000, 2003, 2004). With over 6,600 children entering the Galveston County risk pool through childbirth in 2006 (Alma Garcia, personal communication, January 26, 2007), the 100% BLL screening required for Medicaid beneficiaries and recommended for all Texas children (TDSHS, 2006) would theoretically push Galveston County workload, for BLL screening alone, to 3 or 4 times the current level. Other workload contributions could be expected from educational, case management, and environmental investigation efforts to support the state and national agenda to abolish lead poisoning. The *Texas Strategic Plan to Eliminate Child Lead Poisoning by 2010 Progress Report of June 2006* (TDSHS, 2006) confirms this enhanced screening effort and supports the Healthy People 2010 goal to eliminate childhood lead poisoning by the year 2010 (USDHHS, 2006). Manning requirements addressed in Table 6 suggest community health nurses and environmental investigation support can accommodate the increased demands, but numerous other GCHD CLPPP programmatic elements are already inadequate and have no reserve to address growth. While the program manager position is key, the enormous volume of work needed to develop, implement, and track both new and suboptimal existing processes (see Aim 2 recommendations) quickly exceed the capacity of one FTE for the near future. In the 1997 NCLSH publication, *Designing and Administering Lead Hazard Control Programs: Lessons Learned to Date*, the wide range of staffing number and composition for successful programs is well described. Ultimately, the point is made that staffing needs depend on the complexity of the program requirements. While many forms of workload calculation could be considered, database inaccuracies interfere with highly precise projections. Acknowledging the need to increase screening from 1,500 to 6,000 children per year, in addition to full implementation of the STELLAR tracking system, establishment of billing procedures and numerous other upgrades, it is unlikely that a single FTE program manager could accomplish these requirements in a reasonable timeframe. It is suggested, therefore, that an additional administrative position be established for the first year. At the conclusion of that period, re-evaluation of program needs should be accomplished. In addition to these in-house positions, consideration of in-house versus external professional support is appropriate.

In-house versus outside professional utilization for the GCHD CLPPP was also discussed with the GCHD staff. Ronnie Schultz, Director of Environmental Health Programs at GCHD (personal communication, March 2, 2007), reports that personnel policies are not onerous, do not excessively limit the applicant pool, attract good talent through benefits more than salaries, and permit corrective management of staff problems. Decision-making structure permits quick, decisive, creative solutions to problems with considerable flexibility. The Chief Executive Officer has sufficient authority to make decisions and approve contracts in 2 days that may take up to 2 months elsewhere. To date, the only outside professionals needed on a periodic basis primarily involve lab testing, but the remainder of the work has been easily managed in house. High turnover due to grant-related short term funding and other issues has been somewhat of a problem, but inadequate to confidently recommend contracting out services at this time (D. Beckham and S. Cuellar, personal communication, March 15, 2007; R. Schultz, personal communication, March 2, 2007). These staffing issues combine with other program elements to present substantial challenges, but the time is right for a robust program to support the nationwide initiative to eliminate childhood lead poisoning by 2010. For local realization of this goal, fiscal support can be rate limiting.

Funding Considerations

Funding considerations include short-term grants to jump-start a program and continuity-enabling maintenance funding. The Texas Department of Health (later re-named Texas Department of State Health Services [TDSHS]) grant supported GCHD CLPPP for a few years until 2003. Termination of grant funding was related to a CDC CLPPP policy change. At the time, CDC re-directed these funds to be allocated only to *cities* with a population >100,000. This immediately disqualified Galveston *County*. Even the City of Galveston, at about 57,000 (United States Census Bureau, n.d.), did not meet the minimum population requirement of 100,000. Subsequently, the authority for management of these funds was transferred more fully to TDSHS staff, who in turn formulated a list of the top 15 counties according to magnitude of their childhood lead poisoning problems. Galveston ranked number nine over a five-year average, and funds only accommodated the top five counties. Presently only the top three counties can be funded with available resources, which will likely continue to include no more than Bexar (San Antonio), Harris (Houston) and Dallas Counties for the foreseeable future because of their large population sizes, according to T. Willis (personal communication, March 23, 2007). HUD Lead Hazard Control Grants are still quite numerous and generous, but these require evidence of local matching funds during the application process (HUD, 2006b). Community Development Block Grant funds were suggested as a possible source for matching funds (T. Willis, personal communication, March 23, 2007). Published success stories include examples of effective funding strategies that have overcome this barrier to stability (AHH, n.d.; HUD, 2002). As the CLPPP for GCHD moves forward, billing will provide a portion of ongoing maintenance funding but other financial resources will need to be developed to sustain program integrity. This will be one of many critical tasks demanding the attention of GCHD CLPPP staff, beyond the internal and external coordination issues.

Coordination between Agencies and Agents

Coordination between agencies, contractors, and program staff was reviewed with R. Schultz (personal communication, March 2, 2007), D. Beckham and S. Cuellar (personal communication, March 15, 2007). All agreed that the relationship with the local housing department was cooperative, without the turf issues and other disagreements identified for other CLPPPs (NCLSH, 1977). There were no problems bypassed to avoid involving the housing department or other agencies. While the housing department may identify a home with potential lead hazards without health department input, this was not seen as problematic. The GCHD staff concurred with the housing department actions that included simply restricting who could live in the home before health department input could assess the possible need for environmental investigation of lead hazards. Consequently, the management of risk involved both agencies at a level perceived to be appropriate. Local contractors in the city of Galveston have all had training in the management of lead hazard abatement and remediation. Reputable contractors apply that training. Galveston Historic Foundation (on Galveston Island only) has a paint partnership program providing grants to remove and replace lead paint within specified guidelines. The organization also provides training in lead hazard management. GCHD staff were aware that non-compliance exists in the form of less visible, cost-cutting contractors, but the magnitude of this problem was not known. Program staff and consultants have limited oversight due to the skeletal structure of the local CLPPP, hence they are the decision-makers, feeling a sense of satisfaction in the accomplishment of daily tasks. There was no perception of being left out of the decision-making process.

The programmatic evaluation above provides the foundation for recommendations presented in Aim 2, a proposal to optimize the effectiveness GCHD CLPPP.

Aim 2

GCHD CLPPP Plan

Screening

1. Direct reporting of all BLLs from lab to TDSHS (done; NCLSH, 2001).
2. Establish a routine complete download of all Galveston County BLLs from TXCLPPP to enable rapid identification of new lead poisoning cases, provide visibility on data accuracy issues, and ensure reporting consistency between GCHD and TXCLPPP, which should cover the CDC database as well (action needed; NCLSH, 2001).
3. Continue to emphasize the importance of routine screening (action needed; Smith, 2006; TDSHS, 2006)
    a. Confirm and support Healthy People 2010 and TXCLPPP targets.
    b. Screen all children at 12 and 24 months with capillary BLL, confirming any level >10mcg/dl with a venous sample.
    c. Screen all Medicaid beneficiaries with either blood test or questionnaires at 6, 12, 15, 18, and 24 months of age, then annually until 6 years of age.
    d. Re-align screening protocols with TXCLPPP and Medicaid guidelines as they evolve.
    e. Continue to actively engage with community groups to facilitate educational and screening opportunities with the aim to capture all children in the catchment area.
    f. Targeting high-risk children according to guidance from TXCLPPP will identify optimal locations to initiate implementation or apply limited resources, but many at-risk children may not have formal addresses or other questionnaire answers to ensure identification. Therefore, the current strategy is to test all children early in order to capture as near to

100% of EBLL cases as possible, and eliminate childhood lead poisoning by 2010.

4. Work with TXCLPPP and Medicaid to establish a secure system to identify all Medicaid eligible children in Galveston County, to ensure capture for screening (action needed; NCLSH, 2001; Smith, 2006; TDSHS, 2006).

Case Management

1. Initiate full implementation of STELLAR, as soon as staffing permits, to enable ready identification and tracking of all children receiving CM services (action needed; CDC, n.d.a; NCLSH, 2001).
2. CM should be offered to all children w/EBLLs, as resources allow, but at a minimum, provided at BLLs recommended by the CDC (ongoing; NCLSH, 2001).
3. Develop a protocol to evaluate follow-up capability for CM services (action needed; NCLSH, 2001).
4. Use information from CM services to advocate for needed resources (action needed; NCLSH, 2001).
5. Use information from CM services to advocate for policy changes to improve outcomes for children with EBLLs (action needed; NCLSH, 2001).
6. TDSHS reported Medicaid reimbursement for up to 5 visits with prior authorization (NCLSH, 1999). Work with TDSHS to develop billing procedures and a description of CM services to justify billing rates. Secure reimbursement as quickly as possible (action needed; NCLSH, 2001).
7. Track costs associated with CM services to ensure billing rates reflect actual costs of delivery (action needed; NCLSH, 2001).

Environmental Investigation

1. Continue providing EI services to all children with EBLL ≥20, and those with repeat EBLL between 15 and 19mcg//dL (ongoing; NCLSH, 2001).

2. Offer EI services to children with EBLL ≥10mcg/dl, as resources allow (ongoing; NCLSH, 2001).
3. Continue inclusion of lead dust testing in routine EI protocol (ongoing; NCLSH, 2001).
4. Develop EBLL case close-out criteria in cooperation with CM using STELLAR, to include (action needed; NCLSH, 2001):
    a. Reduction of child's BLL
    b. Control of environmental hazard
    c. Provisions for administrative closure
5. Develop a protocol to evaluate EI follow-up capability (action needed; NCLSH, 2001).
6. Use EI information to advocate for needed resources (action needed; NCLSH, 2001).
7. Use EI information to advocate for policy changes to improve outcomes for children with EBLLs (action needed; NCLSH, 2001).
8. Work with TXCLPPP and Medicaid to secure reimbursement for EI services as quickly as possible (action needed; NCLSH, 2001).
9. Secure EI funding from state general revenue funds (if still available) until Medicaid reimbursement is established (action needed; NCLSH, 1999).
10. Track costs associated with EI services to ensure billing rates reflect actual costs of delivery (action needed; NCLSH, 2001).

Staffing Requirements (D. Beckham and S. Cuellar, personal conversation, March 15, 2007; D. Luna, personal conversation, March 2, 2007; NCLSH, 2001; R. Schultz, personal conversation, March 2, 2007)

1. Program director, one FTE needed, permanent (action needed).
2. Administrative coordinator, one FTE needed, reconsider need at 12 months (action needed).

3. Community health nurse, current staff able to absorb anticipated short-term growth (no action needed).
4. Environmental investigation, current staff able to absorb anticipated short-term growth (no action needed).
5. In-house versus outside professionals (no action needed):
    a. Personnel policies favor in-house staff
    b. Decision-making structure favors in-house staff
    c. Availability of outside professionals support overflow needs
    d. Staff turnover is an issue, but insufficient to justify routinely contracting services at this time.

Annual Budget Requirements

See Table 7 for a summary of budget requirements for the two positions comprising the core of GCHD's CLPPP (action needed). Examples of position descriptions to justify the budget requests are presented below.

Program Director position description: The program director reports directly to the Chief Epidemiologist and is critical to program success. This position requires solid administrative and managerial skills, flexibility, creative problem solving, and an ability to learn from others (NCLSH, 1997). Primary duties will involve supervision of CLPPP administrative coordinator, distribution of duties to ensure that all necessary meetings and tasks are covered, and overall responsibility for the program including, but not limited to, research, development, coordination, implementation, and routine reassessment of program policies and procedures, and coordination of tasks with the CLPPP administrative coordinator, other GCHD staff, and community stakeholders. Additional duties will include: Planning and directing the investigation and acquisition of necessary processes (e.g., billing for case management [CM] and environmental investigations [EI]); networking with agencies vital to the effectiveness of the program, which will require attendance at regional and possibly national meetings of CLPPP organizations;

ensuring that information from CM and EI is used to advocate for needed resources and policy changes to improve outcomes for children with EBLLs; securing full implementation of the STELLAR (CDC, n.d.a) medical and environmental case management tracking system; oversee tracking of costs for CM and EI services to ensure that billing rates reflect actual costs of delivery; establish a process to evaluate capability of CM and EI to perform essential follow-up services; development of case closeout criteria; coordinate development of a plan detailing educational and screening objectives to accomplish the Galveston County portion of Healthy People 2010 goal to eliminate childhood lead poisoning by the year 2010. Training requirements will be established before employment begins and determined by the Chief Epidemiologist, in consultation with experts in the field of childhood lead poisoning prevention.

Administrative Coordinator position description: The CLPPP Administrative Coordinator reports directly to the CLPPP Program Director and provides critical support to ensure accomplishment of all program responsibilities. Primary duties will be coordinated with the direct supervisor and will include coverage at meetings, during absences of the program director, and involvement in many of the issues described in the program director's position description. Training will be required either before or after employment, but at a lesser level than for the program director position.

Table 7

Annual Budget Requirements for GCHD

Childhood Lead Poisoning Prevention Program

Category	Amount ($)
CLPPP Program Director[a]	
Salary	42,500
Fringe benefits[b]	8,880
Travel[c]	3,000
Supplies[d]	7,000
CLPPP Administrative Coordinator[e]	
Salary	30,000
Fringe benefits[b]	6,960
Travel[f]	1,500
Supplies[d]	5,000
Total Direct Costs[g]	104,840

Note. [a]CLPPP Program Director is responsible for the overall program and supervises the Administrative Coordinator. [b]Fringe benefits are estimated at 30% of salary. [c]Includes travel to 8 meetings of TDSHS CLPPP in Austin, Texas, estimated at $240 per meeting and an estimated 120 miles per month in local travel within Galveston County reimbursed at $0.48 per mile. [d]General office supplies (e.g., pens, pencils, paper, notebooks, etc.) estimated at $30 per month. [e]CLPPP Administrative Coordinator reports to and supports the CLPPP Program Director in the establishment of a virtually non-existent program, developing and implementing the processes, procedures, and protocols detailed in position descriptions. [f]Includes travel to 4 meetings of TDSHS CLPPP in Austin, Texas, estimated at $240 per meeting and an estimated 60 miles per month in local travel within Galveston County reimbursed at $0.48 per mile. [g]Excludes other costs including office space, utilities, communications, postage, laboratory supplies, and time contributed to the project by other personnel which will be paid by GCHD from other sources. CLPPP = Childhood Lead Poisoning Prevention Program. GCHD = Galveston County Health District. TDSHS = Texas Department of State Health Services.

Coordination Between Agencies, Contractors, and Program Staff

No significant problematic issues identified between GCHD and the local housing authorities, contractors, or program staff (NCLSH, 2001; R. Schultz, personal conversation, March 2, 2007). No specific recommendations, beyond those discussed in sections above (no action needed).

Secondary Objectives

Focused Interventions to Address Specific Local Challenges

Detailed programs designed specifically for GCHD to address identified challenges are beyond the scope of this paper, but excellent resources to begin the quest for definitive solutions are highlighted with the following examples focusing on two issues of particular significance for GCHD, funding challenges and historic sites.

Funding challenges

This barrier is common to lead hazard reduction programs. Even when grants can be obtained, as GCHD discovered, the short-term financing adds an element of instability as program staff and processes are turned on and off with the flow of financing. Billing for CM and EI services will contribute to continuity and maintenance funding needs, but other financial support will be needed. Despite the transient nature of grant funding, considerable long-term benefit can be realized if these resources are not simply used to support day-to-day program functions, but invested in the development of perpetual funding streams. Lead hazard control funds (from the HUD Lead Hazard Control Grant Program or other locally funded programs) offer considerable flexibility in how those funds are structured. For example, the HUD Lead Hazard Control Grant Program has previously allowed the grantee to select among options, such as grants or forgivable loans. Other HUD funded programs such as HOME or Community Development Block Grant Program (CDBG), state or local programs such as Housing Trust Funds, can all be applied to lead hazard control activities (NCLSH, 1997). The Alliance for Healthy Homes provides an excellent list of best practice illustrations (AHH, n.d.). Examples of creative funding approaches include *Create a Special Real Estate Funding Mechanism* (Alameda County), *Impose Taxes or Fees on Polluters* (California Child Lead Poisoning Prevention Branch), *Make the Most of Fines and Penalties* (San Francisco), *Impose Fees on Real Estate Transactions and Related Professional Licenses* (Massachusetts) and *Access Electric Utility Public Benefit Funds* (New York). These and other examples of solutions to a variety of CLPPP activities are presented in a user-friendly format with links to websites for each primary actor and key participant. Regional expertise in Childhood Lead Poisoning Prevention activities has proven particularly helpful in the identification of prospective funding sources (T. Willis, personal communication, March 23, 2007; B. Reyes, personal communication, September 28, 2006).

Historic preservation

Typically, the primary issue with historic site designation involves the prohibited use of federal funds for lead hazard abatement or remediation. In Houston, however, the more common issue involves pro-active tenant requests for historic designation to protect their neighborhoods from urban renewal projects that have methodically replaced the older homes containing lead-based paint with newer single or multi-family dwellings. Currently the Galveston Historical Foundation grants support residential lead hazard prevention activities on the island. Depending on the magnitude of the problem, it may be worth pursuing an agreement between the Texas Historical Preservation Office and the Texas Department of State Health Services, if that has not already been accomplished.

Useful resources would include the template provided by HUD for grant recipients, the *Prototype Programmatic Agreement among State Historical Preservation Office and the Advisory Council on Historic Preservation and the Lead-Based Paint Hazard Control Grant Recipient* (HUD, 1995). Success stories on this issue include Burlington, Vermont, where an agreement between the Vermont State Historical Preservation Office and the Vermont Housing Conservation Board was accomplished and the City of Stamford, Connecticut, where synergy between the goals of lead hazard reduction and historic preservation was achieved (HUD, 2002). The Alliance for Healthy Homes' list of creative success stories includes an example of property tax credits to cover restoration of historic homes and other buildings in Baltimore, Maryland, coordinated through the Baltimore City Commission for Historical and Architectural Preservation (Baltimore City Commission for Historic and Architectural Preservation, n.d.; AHH, n.d.).

DISCUSSION

Like any journey down a long path, intriguing side paths inevitably beckon for attention, but reaching the primary goal usually means we can't see more than a short distance down the alternate trail before returning to the main road. One such side path encountered on this quest involved the EBLL prevalence data discrepancies between CDC and GCHD, as they relate to sample origin, including venous, capillary, or unknown.

With the discovery that CDC EBLL reporting differed substantially from GCHD reports, an investigation found complexities that exceeded the scope of this paper, but are worth discussion because they illustrate the challenges of this field and the need for staff specifically assigned to manage the CLPPP.

GCHD CLPPP began tracking EBLLs in 1992. Methodology variations have resulted in database configuration inconsistencies from year to year. This situation adversely impacted the ability to track trends across time within the program, but also interfered with the compatibility necessary to compare the EBLL prevalence of Galveston County with Texas and national levels (D. Beckham and S. Cuellar, personal conversation, March 15, 2007).

Since 2003, Texas labs have been required to report all BLLs to TDSHS, where the data is forwarded to CDC. This requirement may have resulted in some bypassing of the more local GCHD, although the evidence is not clear--see discussion below. Also in 2003, CDC Surveillance Data reported 36 EBLL cases for Galveston County while GCHD reported 104 cases for the same year in children under 6 years of age (CDC, n.d.b; GCHD, 2007). For 2005, CDC cited 4 EBLL cases for Galveston while GCHD records indicated 22 (note: CDC Surveillance Data website update provided 2005 values which replaced the 2003 county level data. The 2003 spreadsheet remains available off-line upon request from the author). Personal communication with T. Willis (March 23, 2007), from TXCLPPP, found likely explanations for the 2005 discrepancy.

Essentially, CDC only enters EBLLs for venous samples or repeat (confirmed) samples of capillary or unknown origin into the CDC Surveillance Data spreadsheet. While all non-elevated BLLs are included, regardless of origin, all EBLLs must have confirmatory tests for capillary or unknown samples. T. Willis (personal communication, March 23, 2007) reported that 2005 BLL samples from Galveston County included 1593 capillary, 738 venous, and 430 from unknown sample sources. Of even more interest, most UTMB samples were capillary, while nearly all 4Cs clinic samples were of unknown origin, and neither included the requisite confirmatory test results. Consequently, most data from GCHD's 4Cs clinic and UTMB were not included in the CDC web-based report. This result would suggest to CDC website viewers that Galveston has virtually eliminated its childhood lead poisoning problems, well ahead of the Healthy People 2010 goal.

Around 2003, a couple of significant things happened for GCHD's CLPPP. First, the expiration of TDSHS grant meant the loss of the GCHD CLPPP program manager. Second, the requirement that all BLLs be reported to the state went into effect. Statute did allow labs to report to local health authorities, who in turn would transmit weekly reports to the state. It is unclear, however, whether this change may have contributed to BLL data bypassing GCHD with the advent of some direct reporting by labs to the state. What is clear: Remaining staff at GCHD began requesting BLL data from their own 4Cs clinic and UTMB (D. Beckham and S. Cuellar, personal conversation, March 15, 2007). In retrospect, this decision did not capture all of Galveston County, hence GCHD would under-report BLLs for Galveston County, compared to TXCLPPP and CDC. Further complicating the data integrity issues, there was no manager to coordinate with TXCLPPP and recognize a growing number of changes, such as the evolution of UTMB samples from venous to capillary and failure of 4Cs clinic reports to include sample origin on reports to TXCLPPP.

Regarding capillary samples, it has been interesting to observe the general agreement that their accuracy is sufficient to warrant wide acceptance for screening, yet a reluctance to include them in any database. Not unlike trying to project whether Blue

Ray will replace DVD for HD video formats, the capillary blood sample seems to be in transition. It seems plausible that one reason for slow acceptance in the database would be the fact that all previous data has been venous, and for comparability, it seems appropriate to maintain the fidelity of an all-venous database. Another issue may be the risk of contamination. Very minute lead contamination on the skin could theoretically produce a dramatic increase in the lead concentration of such a tiny sample. Venous samples involve larger blood samples and are drawn from a portion of the anatomy that spends less time in the dirt, hence less contamination risk and less impact if there was any contamination. In response, Harris County Health Department uses industrial wipes specifically designed to remove lead and other heavy metals from the skin prior to capillary BLL testing. There has been no testing of these wipes for this purpose, so the impact is unknown (T. Willis, personal communication, March 23, 2007). If the wipes are extremely effective, could they possibly extract lead from superficial capillaries, introducing a false lowering of BLL that could cause failure to identify a lead toxic child? Or could other unforeseen interactions introduce unexpected variability to the capillary samples? Since they've never been studied for this purpose, these questions are not yet answered, but the wipes are in use today.

As an example of a robust program keeping up with rapidly evolving technology, like capillary testing, and totally engaged with CDC database methodology, the State of Rhode Island would appear to be the holy grail of CLPPPs.

Bringing their statewide EBLL prevalence from 20% to 5% in 10 years was an exceptional achievement they appeared to accomplish through a combination of legislative mandates and outstanding public health initiative. The website provides a very clean, user-friendly explanation of their approach to childhood lead poisoning prevention. Descriptions given reflect use of capillary samples and confirmation with venous draws for EBLLs. Figure 3 presents the Rhode Island EBLL prevalence trend from 1995 to 2004 (Rhode Island Department of Health, n.d.).

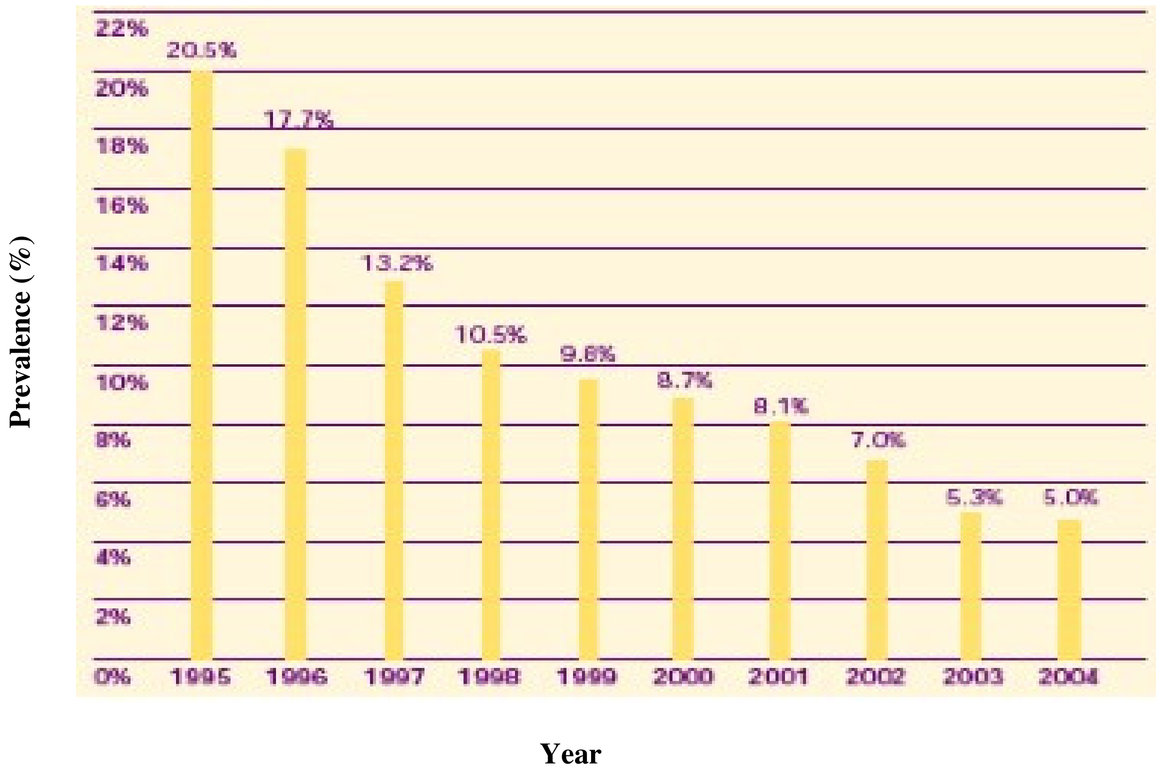

Figure 4. Prevalence of Lead Poisoning in Rhode Island 1995-2004 (BLL ≥10 mcg/dl) for children <6 years old (Rhode Island Department of Health, n.d.).

The various activities undertaken by the RI CLPPP provide an excellent example of effective leadership, intervention strategies, and interagency cooperation. This program remains a superb model for ideas that may work in the Galveston community, but not without the infrastructure to support the program.

In conclusion, CDC database methodology is certainly beyond the scope of this paper as well, but has significantly impacted the perception of Galveston County childhood lead poisoning reflected in this highly regarded national reporting system. Capillary BLL testing appears to be a reliable, less expensive, and more convenient method of sampling that could greatly enhance the ability to screen large numbers of children in a short time. A CLPPP program manager for GCHD would have the opportunity to keep up with these and other changes in the lead poisoning prevention field. The inability to track and respond to these issues has left Galveston County out of the competition for grants, given the appearance at the national level that it no longer has a lead poisoning problem, and allowed considerable degradation of capability to protect its children from lead poisoning. It's time to restore staffing support to the CLPPP at GCHD until sufficient progress can be shown toward the elimination of childhood lead poisoning to legitimately justify a reduction of effort.

CONCLUSIONS

This project ultimately produced some findings that were very predictable, some that were strikingly unexpected, and a direction for GCHD CLPPP that goes a step beyond the specific literature-based recommendations referenced.

The most predictable finding involved the program evaluation results. From the outset it was known that GCHD had no staff hired or designated to specifically manage or provide oversight for the CLPPP. Before turning over any stones, it could be safely assumed that a program evaluation of a virtually non-existent program would fall considerably short of any nationally published recommendations describing an ideal, robust childhood lead poisoning prevention program.

Strikingly unexpected findings included the discovery of wide database discrepancies for EBLLs between CDC and Galveston, but the explanation was even more interesting. The transition issues began to make sense. The growing pains our rapidly changing technology which accompanied the evolution of music storage from cassette tapes to CDs and MP3s was also experienced with document storage transitions from floppy disks to thumb drives. During these transitions, there were areas of uncertainty, like the Blue Ray versus DVD future for HD videos now. Capillary samples have been sufficiently reliable to earn a spot in the action, but not yet fully accepted for treatment or even database reporting. It appears that UTMB introduced capillary BLL sampling to Galveston County, but in a way that produced some unanticipated repercussions. GCHD staff didn't know about the capillary samples and CDC rejects them from Surveillance Data inclusion, without confirmation. All of these issues can be addressed, but they were quite unexpected at the outset of this study.

Finally, a new direction that seems reasonable, but wasn't found specifically recommended in the literature, involves the incorporation of capillary blood sampling. A parallel approach is proposed. Since UTMB, Harris County Health Department, Rhode Island, and other sites (T. Willis, personal communication, March 23, 2007; Rhode Island Department of Health, n.d.) have already implemented capillary BLL sampling, it is not a surprising recommendation that widespread use of capillary screening be encouraged to target the 100% BLL screening recommended by TXCLPPP and Medicaid. The parallel recommendation would be to initiate a study of D-wipes (Esca Tech, 2003) for skin preparation prior to capillary BLL testing. D-wipes are designed to remove heavy metals, and specifically lead, from the skin after industrial exposures such as battery manufacture, paint dust, and firing ranges. A Medline search did not locate any studies to assess the use of D-wipes with capillary BLL sampling, but the distributor's website advertises D-wipes for use prior to capillary blood lead level testing (Esca Tech, 2003).

In summary, GCHD staff have done a phenomenal job with minimal resources. In order to address the high local prevalence of childhood lead poisoning and respond to national and statewide efforts to eliminate this problem by 2010, GCHD will need staffing support. To obtain staffing, GCHD needs funding. Immediate steps can include efforts to secure billing capability for CM and EI services, in addition to encouragement of 4Cs and UTMB providers to expand capillary screening, but to ensure follow-up with venous confirmation of all EBLLs and include sample source with every lab report to TDSHS. Additional support from future MPH, nursing, or other graduate students could include development of a grant application or pursuit of sustainment funding options like those provided in the HUD Success Stories (HUD, 2002) or AHH Illustrations (AHH, n.d.). The time is right for an aggressive resurgence of effort. Opportunities for funding, staffing, and program development can enable the Galveston community to finally gain control of this insidious, persistent hazard. Swift action is needed to minimize this threat to the children of Galveston County who will soon become either productive or dependent citizens, depending on how well we protect them now.

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APPENDIX

CHILDHOOD LEAD POISONING PREVENTION PROGRAM (CLPPP) EVALUATION FOR GALVESTON COUNTY HEALTH DISTRICT (GCHD)

Goals

- Establish GCHD program baseline
- Compare to national consensus standards
- Target use: To support resource & funding requests to sustain current program & launch new initiatives

1. Staffing (National Center for Lead-Safe Housing [NCLSH], 1997, pp. 43-46)
    a. Minimum
        i. Program Manager: Does GCHD have a pgm mgr? If so, how many hours/week?
        ii. County Health Nurse: How many hours/week are currently needed from County Health Nurse?
        iii. Environmental Inspections: How many inspectors, for how many hours/week, are currently needed by GCHD?
        iv. Relocation: How much manpower is currently needed for relocation?
    b. In-house versus outside professionals?
        i. Personnel Policies. Which of these apply: Months to hire, onerous requirements severely limit applicant pool, low salaries limit attraction of good talent, or policies restrict correcting staff problems?
        ii. Jurisdiction's Decision-Making Structure. Are the abilities to "make decisions quickly, devise creative solutions to problems, be flexible in addressing issues (NCLSH, 1997, p. 45)" hampered by unalterable established procedures?

iii. Availability of Outside Professionals. Does a deficiency of qualified professionals exist?

iv. Ability to retain staff. Is staff turnover an issue for GCHD?

2. Coordination between agencies (NCLSH, 1997, pp. 47-49)

   a. Health dept and housing dept.

      i. Are there turf issues inhibiting cooperation?

      ii. Disagreements about which dept is responsible for which actions?

      iii. Bypassed the problems by not involving other agency at all?

      iv. Does housing dept ID housing for lead hazard intervention w/o input from health dept re' where kids live?

      v. Are contractors and program staff current on lead hazard skills?

      vi. Are contractors used to non-compliance (resistant to enforcement)?

      vii. Do program staff and consultants feel a part of the decision-making process, appreciated and conscientious in daily tasks?

3. Screening

   a. *Another Link In the Chain-Update* (ALITC) Recommendations (NCLSH, 2001)

      i. Does TX require labs to report ALL blood lead levels to TxCLPPP? (Yes, according to NCLSH, 2001; see question 4.b.i.4.)

      ii. Does GCHD have an effective system to identify new cases of childhood lead poisoning (>20)? Is the #/mo or yr readily available? If so, has this system been evaluated for effectiveness? In other words, has the duration of time from 'date-reported' until 'case-identified with f/u initiated' been routinely assessed?

      iii. Does GCHD emphasize importance of routine screening? How?

      iv. Does TxCLPPP work with Medicaid to ensure screening for Medicaid beneficiaries?

v. Does Medicaid permit tracking of insurance status? (Specifically, Medicaid enrollment; NCLSH, 1999)

vi. Any capillary blood lead level testing? (Addresses standardization of blood lead data; NCLSH, 1999)

b. Is there a screening plan?

i. Does it target high-risk <6yo?

1. ID by housing before 1950 locations?
2. ID by other EBLL siblings?
3. ID by zip code or census tract with high EBLL prevalence or high # homes built before 1950?
4. By 2003 *all* BLLs reportable to TDSHS (Smith, 2006). Is this happening?

ii. Does it target All Medicaid <6yo?

1. Is there a plan to increase screening of Medicaid-eligible children in GCHD catchment area?

iii. Who does screening, besides primary care providers? Is there a GCHD screening option at schools, health fairs, etc? (TDSHS, 2004)

4. Case management

a. ALITC-Update Recommendations (NCLSH, 2001)

i. Does GCGH have a protocol that identifies minimum standards for case management *initiation*, *performance*, and *tracking*?

ii. Standards for *initiation*:

1. Are case management services offered to all children with EBLLs?

a. If so, with what trigger? Specifically,

i. Is case management being provided for all children with repeat EBLLs between 15 and 19?

ii. Is case management being provided for all children with EBLL $\geq$20?

iii. When resources allow, is case management being offered to children w/EBLL $\geq$10?

iii. Standards for *performance*:

1. Is GCHD being evaluated for ability to provide case management services?
2. Is GCGH being evaluated for effectiveness of case management services in lowering EBLLs? If so,
    a. Is this info being used to advocate for needed resources?
    b. Is this info being used to advocate for policy changes to improve outcomes for children with EBLLs?
3. Is case management being provided by professional-level staff?
4. Does GCHD currently receive Medicaid reimbursement for case management services? (+ for TX 1998 & 2000; other states range from $25 for one "educational" visit to $1240 for eight months of follow-up)
    a. If yes,
        i. What rate for what level of service?
        ii. Has recent re-evaluation of reimbursement rates been done to ensure rates are based on actual cost and effectiveness of measures?
    b. If not currently billing, are immediate steps being taken to secure reimbursement?

iv. Standards for *tracking*:

1. Does GCHD have a system to identify children receiving case management services? (#/mo or yr?)
2. Does GCHD have a system to track children receiving case management services? (i.e., up-to-date progress documentation?)
3. Does GCHD have standards for data collection and outcome measurements?

5. Environmental investigations

a. ALITC-Update Recommendations (NCLSH, 2001, unless otherwise indicated)

i. Does TxCLPPP work with Medicaid to ensure reimbursement for environmental investigations?

ii. Is environmental investigation being provided for all children with repeat EBLLs between 15 and 19?

iii. Is environmental investigation being provided for all children with EBLL ≥20?

iv. When resources allow, is environmental investigation being offered to children w/EBLL ≥10?

v. Is lead dust testing part of routine protocol?

vi. Is there a closeout criteria protocol? (NCLSH, 1999, pp. 41-42) If yes, does it include:

1. Documented reduction in child's BLL?
2. Documented control of environmental lead hazard?
3. Post intervention testing?

vii. Is the ability of GCHD to provide follow-up services being evaluated?

viii. Are GCHD follow-up services being evaluated for effectiveness of decreasing children's environmental exposures?

ix. Is this info being used to advocate for needed resources?
x. Is this info being used to advocate for policy changes to improve outcomes for children with EBLLs?

VITA

Colonel Steven T. Lamb, a native of Washington State, began a medical career in 1974 with the completion of an Associate in Applied Arts degree in Respiratory Therapy and worked as a Respiratory Therapy Technician. He attended premed studies at Seattle Pacific University and graduated with a B.S. in Biology and a B.A. in Chemistry, followed by an M.D. degree from the University of Washington School of Medicine in 1984. A 3-year residency in family practice was completed in 1987 before starting 12 years as a rural family practice physician in Eastern Washington State. Col Lamb joined the U.S. Air Force as a Major in 1999, holding positions including Chief of the Medical Staff and Squadron Commander. He promoted to the rank of Colonel in 2005.

Col Lamb and his wife of 30 years have five children and one grandchild.

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This dissertation was typed by Steven T. Lamb.

The views expressed in this paper are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.