Lead and Crime in Manitoba:

Urgent action needed

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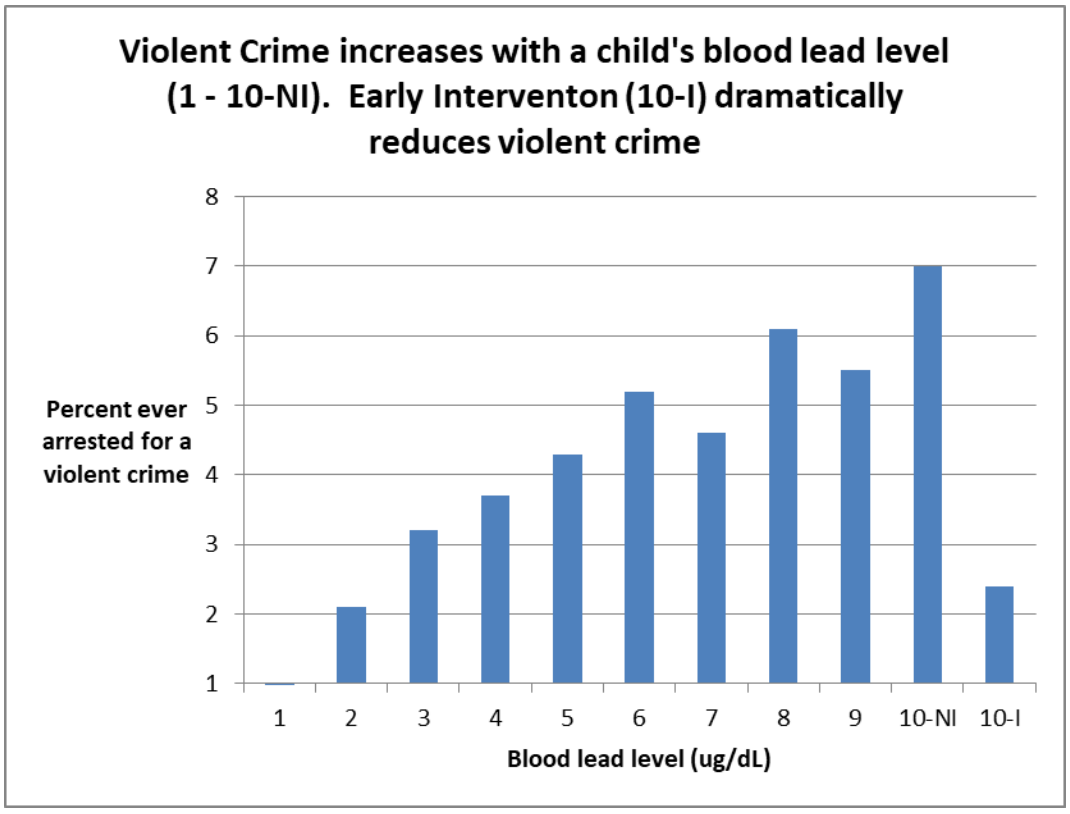
Manitoba Liberal Caucus report



“Lead poisoning is the most significant and prevalent disease of environmental origin in US children” -Silbergeld 1997

Lead exposure contributing to violence and crime is, “a public health crisis with serious social justice implications” -Emer et al 2020

“mounting evidence [supports] that preschool lead exposure affects the risk of criminal behavior later in life. … especially affects juvenile offending and related trends in index crime (mainly property crime rates and burglary)… Violent crime trends and shifts to higher adult arrest rates suggest blood lead also affects violent and repeat offending.” -Nevin 2007

“The hypothesis that murder rates are especially affected by severe lead poisoning is consistent with international and racial contrasts and a cross-sectional analysis of average 1985-1994 USA city murder rates.” -Nevin 2007

“1941-1975 gasoline lead use explained 90% of the 1964-1998 variation in USA violent crime.” - Economist Rick Nevin, from a study published in 2000, and reported by CTV news March 7, 2013

“We can either attack crime at its root by getting rid of the remaining lead in our environment, or we can continue our current policy of waiting 20 years and then locking up all the lead-poisoned kids who have turned into criminals.” -Drum 2016

“Cleaning up the rest of the lead that remains in our environment could turn out to be the cheapest, most effective crime prevention tool we have.” -Drum 2016

“Children found to have a blood lead level higher than 5 ug/dL (0.24 umol/L) should be investigated thoroughly and any identified exposure sources should be mitigated as soon as possible.” - Canadian Pediatric Society 2019

“The impact of lead is intergenerational. A mother with high lead levels passes the problem on to her children.” -Gerrard 2020

Legend for Cover Figure: Children in Charlotte-Mecklenberg County in North Carolina with higher blood lead levels showed an increase in arrests for a violent crime with a gradient showing the effect of blood lead levels starting as low as 2 ug/dL and going up to 10 ug/dL. NI= No Intervention. The 10-NI bar shows the level of arrests for a violent crime for children whose first blood lead test was 10 ug/dL and who received no intervention. I = Intervention. The 10 – I bar shows the reduction in arrests for violent crime following the intervention to reduce lead exposure and the impact of the lead. The results show a dramatic reduction in arrests for violent crimes as a result of early intervention. More details of this study are on pages 52-55. Figure is redrawn from Billings and Schnepel 2018.

CONTENTS

Summary:

Lead is one of the most dangerous substances at an individual and a society level. Its impact is intergenerational. A few decades ago, lead was a common additive in gasoline, in paint, in drinking water pipes and was emitted by industries resulting in toxic levels in some Winnipeg neighbourhoods. Scientific studies link high levels of lead exposure, and high blood levels to learning difficulties in children and to behavioural changes including increased impulsive and aggressive behavior and ADHD. These changes lead to poor school performance, dropping out of school, to juvenile delinquency and to crime. High lead levels in Winnipeg may be a factor in Winnipeg's reputation as the "Murder capital of Canada." This report explores the role of lead in contributing to crime, particularly violent crime in Winnipeg.

A number of industrialized areas in Winnipeg have high blood lead in soil from emissions from industry, airports and traffic, and contain older houses with lead pipes for drinking water. In areas of low income, these factors are worsened by poor nutrition which increases lead absorption and toxicity. This report follows the evidence that there is a lead to crime pathway with lead changing the brain so it is vulnerable for the development of antisocial behaviour, mental illness, addictions and criminality. Lead may play a central role in the intermixing of crime with poverty, substance abuse and mental health status - including neurodevelopmental conditions and mental illness. In some circumstances 50-90% of crime or the changes in crime, particularly violent crime, have been explained by the lead exposure of pregnant women or infants.

In this report we document that a substantial number of Manitobans are showing high blood levels of lead. We also provide some evidence relating the geography of lead exposure and the geography of brain health issues and crime in our province.

Addressing high lead levels in young children is needed. Studies show that interventions including widespread screening, lead remediation, nutritional assessment, medical evaluation, developmental surveillance and public assistance referrals are effective in improving the health of children and in reducing the incidence of crime, especially violent crime. In one study the impact on violent crime was dramatically reduced. Moreover, as studies in Chicago have shown, widespread screening and intervention are also effective in reducing racial inequalities. In Manitoba, we need to start screening children more broadly and to use this intervention approach as soon as possible for every child with a high blood lead level.

This report puts a new perspective on factors contributing to violent crimes including sexual violence, domestic violence and intimate partner violence and homicide. It may enable new approaches to understanding the biology of violent offenders and new approaches to decreasing such violence. During the COVID-19 pandemic with concern for increased addictions and crime, effective action is more important and more urgent than ever.

There are four major conclusions from this report:

1) **Lead is an important cause, or substantial contributor to, criminal activity.** Lead exposure from various sources results in increased crime, particularly property crime and violent crime. Up to 50-90 % of crime, or of the changes in crime rates, is related to lead in some circumstances. The effect of lead on crime appears to result from its ability to produce a learning disability; and to increase impulsivity, aggressiveness and a lack of self-control. The studies are so persuasive it is to be hoped that never again will there be a major treatise on the causes of crime without considering the impact of lead. The pathways leading from lead exposure to learning and behavioural problems and to crime are various. They include the impact of lead to increase mental health and addictions issues, and to cause or perpetuate poverty. They include an impact of poverty to increase lead exposure, lead absorption and lead toxicity. The impact of lead can be intergenerational.
2) **There is an urgent need for action.** There have been too many delays already in addressing the problem of lead contamination and its effects on Manitobans. Now at the time of the COVID-19 pandemic there is a need more than ever to address this issue. Manitoba needs to move quickly to screen, between age 1 and 3, all children born in areas of Manitoba exposed to industrial lead sources, with lead water pipes and with lead paint in the homes, and to move beyond this to universal screening. It is essential to reduce lead exposure and it is vital to use current proven best practices with any child having a lead blood level of 0.24 umol/L or higher. These best practices include lead remediation, nutritional assessment, medical evaluation, developmental surveillance and public assistance referrals. In one study, these best practices, employed to help children identified as having high lead levels at 1 to 2 years of age were able to almost completely reverse the adverse impact of lead on violent crime.
3) **Cost-benefit analyses show substantial net benefits from investments to address and reduce lead exposure**. One study shows $17 or more in benefit for every dollar invested. Lead deserves special attention in addressing factors which contribute to crime because it is a preventable cause of crime, because reducing lead exposure may positively impact learning and behavioural issues, addictions and mental illnesses involved in the pathway from lead to crime, and because of the substantial net benefits from each dollar invested. Such benefits include major improvements in children and adult's health, improvements in their employment as adults and a reduction in societal inequalities, the latter being clearly demonstrated in a study in Chicago.
4) **Further research is needed to better understand and address the reasons for high rates of crime in specific groups**, including those in the Indigenous community, those who are on low incomes, children in the care of child and family services and children, youth and adults with varied brain health conditions - including intellectual disabilities, learning disabilities, mental health concerns and those with addictions issues.

Preface:

The journey that led to this report began with my training in medicine and pediatrics, and learning about lead toxicity, lead poisoning and the role of pica (a child's habit of putting things in its mouth, perhaps partly to explore and perhaps a sign of a child whose diet is deficient and who is searching for missing nutrients). In my time doing medical and health research, nutrition was one of my interests, but I was never involved in studies of lead. When I became an elected politician, I was forced to pay more attention to crime and the causes and antecedents of crime. Crime is one of the top concerns of many voters. In the summer of 2016, when Judy Klassen, Cindy Lamoureux and I put together a report on brain health, one aspect of this effort was looking at the relationship between brain health and crime, and in trying to understand why Manitoba has such a high crime rate (Gerrard et al 2016). We addressed the fact that Manitoba has an extraordinarily high rate of crime compared to the rest of Canada. We suggested that there must be factors in Manitoba affecting the crime rate in our province. We even suggested one contributor might be the fact that Manitobans eat less fish and have lower levels of the long chain omega 3 fatty acids which some evidence suggests can decrease violence. We did not mention lead as a potential culprit, though we did mention neurotoxins in general and we did refer to the work of Walsh (2012) which suggested that an overload of heavy metals including lead can be related to behavioural issues, ADHD and crime. Since that report was completed in 2016, exposure of people in Winnipeg to lead from industrial sources and in our water supply has been in the news. I started reading more about the association between lead exposure and crime, and became intrigued enough by what I read to delve deeper. As Health Critic, I asked questions in the Manitoba Legislature on lead contamination and its relation to health concerns including ADHD and mental illnesses, but there has been little action. Indeed, when I asked the government in Question Period to look into the mental and physical health of people in areas where there was lead contamination, the Minister of Sustainable Development, the Hon. Rochelle Squires called my suggestion that there may be a connection between people's mental health and lead exposure as a "false accusation" and that it was "shameful" of me to be fear mongering (Appendix 12).

In 2019, I became the Justice Critic for the Manitoba Liberal Party, and in preparation for the 2019 election, looked into the recent (since 2016) increase in property crime in River Heights and in Winnipeg, and its possible relationship to an increase in methamphetamine use in Winnipeg. In the process of doing this work, I looked further into the relationship between lead exposure and crime. November of 2019, saw the release of results from investigations into lead across Canada by the Concordia Institute for Investigative Journalism, and many collaborating reporters, editors, students and faculty members from across Canada. These reports exposed widespread concerns about lead in drinking water in Canada (Tower 2019a, 2019b; Kimmett et al 2019). In October and November 2019, I raised my growing concerns about the connection between lead exposure and crime in the Manitoba legislature (Appendix 12). There was little pick up from the government, the official opposition or the media. I realized I would have to take this further. The present report is the result.

Acknowledgements:

I acknowledge that Winnipeg, where much of this report was written, is on Treaty One Territory, that Manitoba is the land of the Anishinaabe, the Cree, the Oji-Cree, the Dakota and the Dene and that Manitoba is the homeland of the Metis Nation. We are at a time of reconciliation, following the report of the Truth and Reconciliation Commission of Canada. In acknowledgement of reconciliation, Appendix 8 has been included to link this report to specific calls to action from the Truth and Reconciliation Report. I want to thank many individuals who have helped me learn about crime and about lead. It has been a pleasure to work with my colleagues Dougald Lamont, Leader of the Manitoba Liberal Party and Cindy Lamoureux – MLA-Tyndall Park, and to work with our staff including Shandi Strong, David Mintz, Colleen Reader, Colin Roy, Richard Davies and Julia Sisler. Thanks are also due to Elder Robert Wavey, Marion Willis, Bonnie Bricker, George Bricker, Dr. Peter Markestyn, Dr. Krishnamurti Dakshinamurti, Sid Frankel, Shirley Thompson, Michelle Berger, Ray Ali, Thomas Rempel-Ong, Don Hornby, Yvonne Swiderek, Pat Pruden, Nikki Gerrard, Rachel Smith and Scott Smith who reviewed this report. I also thank many individuals who have brought forward their concerns to us about lead contamination and its impact, in particular in regions of Winnipeg which have been affected by industrial exposure to lead including the Weston School area (Janice Clark) and the area near the St. Boniface industrial park (The South St Boniface Residents Association). I thank, in particular, Patti Sonntag of the Concordia Institute for Investigative Journalism, and Michele Prevost , Chaire Industrielle CRSNG en Eau Potable at the Polytechnique Montreal and Diana Fishbein, Professor of Human Development and Family Studies at Penn State University for their helpful comments. I also want to thank the many individuals who have contributed the large body of research which currently exists on the adverse impacts of lead on human health and the relationship between lead exposure, blood lead levels and crime. The current work builds on the foundational efforts that have been done over many years. Lastly, I want to thank my wife, Naomi, who has put up with me spending an inordinate amount of time during the last year in investigating this area and in writing this report.

Lead, learning and behavioural issues, juvenile delinquency and crime:

Overview:

The evidence links crime to the impact of lead on learning and behavioural issues, to increase hyperactivity and impulsivity, to decrease IQ and to increase juvenile delinquency, substance abuse, mental illness and homelessness. In essence, the brain dysfunction and learning difficulties caused by lead appear to be a fundamental reason why lead is associated with juvenile delinquency and crime. Particularly responsible may be the impact of lead on the frontal brain, on executive function and on impulse control. High levels of lead in the body also appear to contribute to brain dysfunction in a way that leads to substance abuse and mental illnesses which can also contribute to crime. Overall, the direct and indirect impact of lead is to contribute to juvenile delinquency and to crime.

The likelihood of high lead levels is often greatest in areas where people with low incomes are living. As we show in this report, the impact of lead is made worse by poverty, by family instability and by socioeconomic circumstances. Thirty years ago, Deborah Denno studied this. Her work, the "BioSocial Project", was able to examine intensively, "with multiple measures of key variables, a large sample of children both before and after the start of their criminal careers." In her book, "*Biology and Violence*" she said, "should lead poisoning occur early in life, during either prenatal development (through ingestion by the mother) or early childhood, a child may develop problems in learning and behaviour, particularly in the presence of other crime-facilitating factors, such as an unstable family environment or low socioeconomic status. The probability of criminal behaviour would be relatively great for this child" (Denno 1990).

Lead poisoning is preventable, and children who have high lead blood levels can be helped. Denno (1990) says, "many of the factors that strongly predicted crime and violent behaviour could be prevented. … Lead poisoning … illustrates the powerful impact that a preventable toxin can have on the lives of individuals." Studies, to be discussed later, further emphasize the importance and the effectiveness of addressing the exposure to lead as well as treating the learning disability and behavioural issues in order to reverse the impact of lead on juvenile delinquency and on crime.

The role of lead in contributing to brain dysfunction and learning disabilities:

Children are particularly sensitive to the impact of lead on the brain. As Lidsky and Schneider (2003) explain, "a greater proportion of ingested lead is absorbed from the gastrointestinal tract of children than of adults. In addition, a greater proportion of systemically circulating lead gains access to the brain of children, especially those 5 years of age or younger, than of adults. Finally, the developing nervous system is far more vulnerable to lead's toxic effects than the mature brain."

It has been known for many years that exposure to lead, particularly in utero and in the early years of childhood, is associated with and causative of brain dysfunction and disorders of learning and behaviour in children. The accumulated data supporting this is large. Studies have found that certain brain

functions and certain types of learning are particularly affected by lead. For example, exposure to lead has been shown to have significant effects on the brain to reduce impulse control (Loeber et al 2012), to contribute to a range of conduct problems (Marcus et al 2010), to Attention Deficit and Hyperactive Disorder (ADHD) (Goodlad et al 2013, Nigg et al 2008, 2016), to reducing IQ, to decreased cognitive ability and to decreased academic achievement in reading and math (Needleman and Gatsonis 1990, Bellinger et al 1992, Pocock et al 1994; Banks et al 1997; Lidsky and Schneider 2003, Matsuzawa et al 2001, Coulton 2020). The impact of lead can extend to produce defects in neuromotor function, in attention and executive function and in auditory or visual function (Government of Canada 2013). The impact of lead can be very large. **Exposure to lead early in life has been associated with a six-fold increase in reading disability and a seven-fold increase in dropping out of high school (Needleman et al 1990**). A study by Nevin (2009) provides evidence that "1936–1990 preschool blood lead trends explain 65% of the 1948–2001 variation in USA mental retardation (MR) prevalence, 45% of the 1953–2003 variation in the average scholastic achievement test (SAT) verbal score, and 65% of the 1953–2003 variation in the average SAT math score."

The Government of Canada's "Final Human Health State of the Science Report on Lead" (2013) summarizes the numerous neurodevelopmental effects of lead and includes: increased inattention and hyperactivity in children and increased diagnosed ADHD, decreased performance on standardized tests of reading and math in grade 4, decreased performance on tests of standardized educational outcomes in 7-8 year olds, decreased math and reading skills in 6-16 year olds, lowered academic achievement in children age 4-11, deficits in cognitive function, a lowered IQ and increased antisocial behaviour.

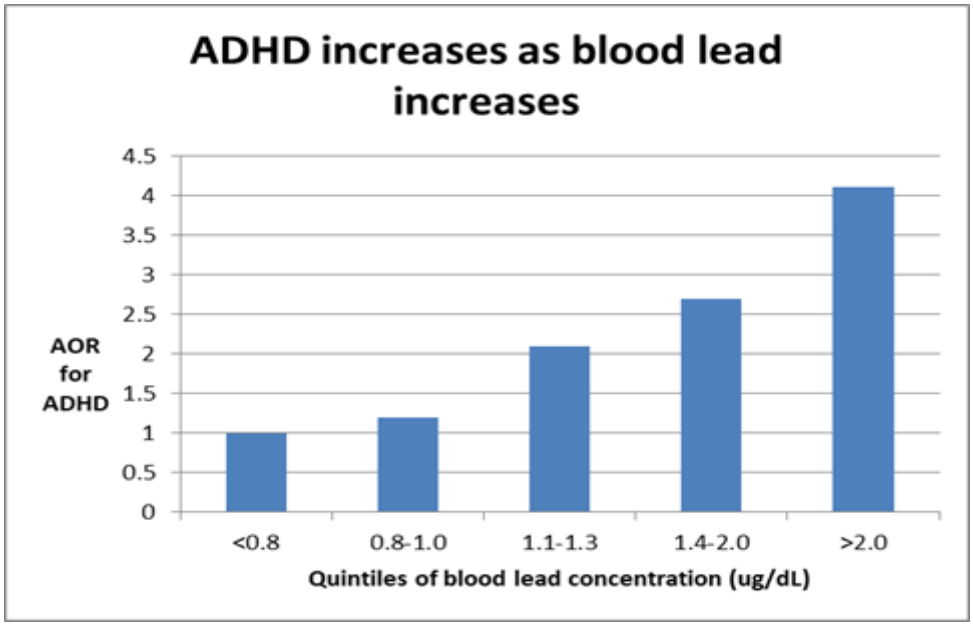


Figure 1: An evaluation of 3879 children by Braun et al 2006 showed that as blood lead concentration increases above 1 ug/dL (0.05 umol/L), so does the likelihood a child will have ADHD. AOR = Adjusted odds ratio. This figure is redrawn from Braun et al 2006.

The effects of lead exposure have been shown to occur at low blood levels of lead (Figure 1). The diagnosis of ADHD was based on the child having both parent report of ADHD diagnosed by a health professional and stimulant medication use. Results were based on a study of 4704 children aged 4-15 years of age who were participants in the U.S. National Health and Nutrition Examination Survey 1999-2002. A national sample of children in the United States estimated that 25% of children with ADHD when aged 8-15 years of age are attributable to lead exposure and high blood lead levels (Forelock et al 2009). It is to be noted that effects of lead levels on intelligence and on crime can be seen to start at similar concentrations to the effect of lead on ADHD as shown in Figure 1 (Lanphear et al 2000, 2005).

The non-neurological effects of lead toxicity are listed in Appendix 6. The cellular and biochemical mechanism of action of lead is discussed in Appendix 7.

The role of lead in causing and/or contributing to antisocial behaviour and juvenile delinquency is significant:

Needleman et al (2002) studied bone lead levels in relation to juvenile delinquency. These authors studied 194 youth, aged 12-18, who were arrested and adjudicated as delinquent by the Juvenile Court of Allegheny County, Pennsylvania. They found that the delinquents, compared to age matched control youth were four times more likely to have high bone lead levels.

Aizer and Currie (2017), in a much larger study, evaluated 120,000 children born 1990 to 2004 in Rhode Island, a state which has done multiple blood lead tests on children. Using detailed and very local information on blood lead levels and lead exposure, the authors found that increased preschool blood lead levels are associated with an increase in anti-social behavior and juvenile delinquency as measured by school suspensions and juvenile detention (incarceration). Specifically, each one ug/dL increase in blood lead increased the probability of suspension from school by 6.5 to 7.0 percent for boys and by 6.4-9.3 percent in girls. **Thus, an increase in blood lead level from 5 to 10 ug/ml may be associated with an increase in school suspensions of more than 30 percent.** Higher blood lead levels in children were also associated with higher levels of incarceration later in life. A one ug/dL increase in blood lead increased the probability of detention/incarceration by 57 percent in boys. These findings are corroborated by other research studies which also link preschool lead exposure to juvenile delinquency and to aggressive behavior (Denno 1990; Dietrich et al 2001; Needleman et al. 1996, Coulton 2020).

The Denno (1990) study, called the BioSocial Project, surveyed 987 children in Philadelphia. It looked at children who were studied perinatally and in early childhood (from 1959-1966) and were then followed up with an evaluation of their police records from ages 7 to 22. Denno measured multiple key variables on a large sample of children before and after the start of their criminal careers. In an exhaustive analysis, she found that, “delinquency in males was most strongly associated with three factors: amount of time the father was unemployed, lead intoxication at age 7 and number of household moves.” It is striking that when looking at multiple variables lead exposure is one of three variables strongly associated with juvenile delinquency.

More recently, Sampson and Winter (2018) looked at antisocial behaviours including destroying things belonging to his/her family or others, displaying cruelty, bullying or meanness to others, lying, cheating,

being disobedient at school and not feeling guilty after misbehaving. They studied children in Chicago. Their results showed "a significant relationship between childhood lead exposure and antisocial behaviour in both childhood and adolescence". They conclude "that the biological assays of lead exposure in childhood directly predict adolescent antisocial behaviour using three different modeling strategies and controlling for theoretically informed confounding factors and potential mediating pathways." The authors also were able to "establish a sturdy and expected association between adolescent antisocial behaviour and arrest."

Lead exposure as a cause or contributing factor to substance abuse:

Emma Jane Rose and her colleagues (2019) note that, "perturbations in brain structure and function are commonly viewed as critical mediators between the developmental context (relevant genetics and environmental factors) and the cognitive, behavioural, and affective phenotypes that precede problematic substance use." They also note that brain health conditions commonly found in those exposed to lead including conduct disorder (CD), attention deficit hyperactivity disorder (ADHD) are, "strongly and consistently related to the risk of substance abuse" (see also Armstrong and Costello 2002). Fishbein (2011) also recognized the following conditions as increasing risk for substance abuse – "attention deficit, conduct disorder, depression, novelty-seeking and adversity." All these conditions can result from lead exposure.

Consistent with the concept that exposure to lead contributes to increased intake of alcohol and/or drugs and to substance abuse are the following observations. Nation et al (1986) and Virgolini et al (1999) found that rats receiving low doses of lead consumed more ethanol than control rats. Investigation of the mechanism of this effect has provided evidence that developmental lead exposure can modulate the ethanol metabolizing enzymes in a fashion that results in "increasing vulnerability to addictive behaviors, including excessive ethanol intake" (Virgolini 2017). Consistent with this Fishbein (2008) found that animals treated with lead either pre or post-natally self-administer opiates at a much higher rate than untreated animals (Fishbein 2008). Dietrich et al (2001) found that teenage alcohol consumption and use of marijuana were positively correlated with postnatal blood lead levels. Consistent with this, a higher lead exposure has been found in female injection heroin users compared to age adjusted community dwelling women who were not using heroin (Fishbein et al 2008). In addition, Feigenbaum and Muller (2016) found that individuals living in cities with lead water pipes were more likely to develop cirrhosis of the liver (which they speculate is related to increased alcohol consumption) than cities with iron water pipes. **While the evidence is not conclusive, the evidence strongly suggests that lead exposure is a contributing factor to individuals being susceptible to substance abuse and addictions.**

In addition there is evidence that increased ethanol intake may increase lead blood levels and the accumulation of lead in the brain (Gupta and Gill 2000). The impact of lead to promote ethanol consumption combined with an action of lead to increase lead levels may create a vicious cycle of increased ethanol consumption and increased addiction.

Lead exposure as a cause or contributing factor to mental illness:

Liu et al (2014) found that an elevated blood lead level was significantly associated with the internalizing mental health conditions of anxiety and depression as well as with pervasive developmental problems. Reuben et al (2019) followed a cohort of 579 children born between April 1, 1972 and March 31, 1973 in Dunedin, New Zealand who had blood lead levels measured at 11 years of age. Members of this cohort were followed up in December 2012 when they were 38 years old. Each 5 ug/dL increase in blood lead level at age 11 years of age was associated with a 34% increase in general psychopathy driven by internalizing (including anxiety and depression) symptoms and thought disorder symptoms. The results are consistent with those of Rhodes et al. (2003) who found increased anxiety, phobic anxiety and depression in those with higher lead levels and the findings of Bouchard et al (2009) who found higher blood lead levels were associated with a 2.3 fold increase in major depression and a 4.9 fold increased risk of panic disorder. Also consistent with these findings is work of Winter and Sampson (2017) showing that higher lead levels in early childhood are associated with increased anxiety or depression, increased impulsivity and an increased body mass index. **Taken together, these findings show that lead exposure in children and increased blood lead levels in adults are associated with an increased likelihood of mental illnesses particularly anxiety and depression**.

Lead as a contributor to homelessness:

Two studies provide evidence that lead contributes to homelessness. Parker et al (1991) found that when homeless children and mothers in Philadelphia were assessed, the children had significantly higher levels of lead. Coulton (2020) studied 10,470 children in Cleveland, Ohio and found that children who had an elevated blood lead level ($\geq$ 5ug/dL) were significantly more likely to use a homeless service (45% higher) or to use an emergency shelter (73% higher).

Lead exposure as a primary cause and/or major contributing factor to crime is now based on very substantial evidence:

A variety of studies show an association between exposure to lead, blood lead levels and crime - particularly with property crime, violent crime and homicides. The relationship between exposure to lead and crime is present with various different types of exposure whether from leaded gasoline, lead in paint, lead in water pipes or lead from industrial activity. A notable example is a significant association between air lead concentrations and the incidence of homicide across counties in the United States (Stretsky and Lynch 2001). A separate prospective study showed that when pregnant women and their children were followed, the children of mothers with higher prenatal blood lead levels and children with higher postnatal blood lead concentrations had higher rates of total arrests and/or arrests for offenses involving violence in early adulthood (Wright JP et al 2008). This study was done of children born between 1979 and 1984 in poor areas of Cincinnati with a high concentration of older, lead contaminated housing. For every 5 ug/dL increase in blood lead levels at six years of age, there was a 50% increase in the risk the child would be arrested for a violent crime as a young adult.

Denno (1990) in Philadelphia, found, in a study of multiple variables, that "the number of adult offenses by males is most strongly influenced by four factors: mother's and father's education, lead intoxication at age 7, the amount of time the father was unemployed, and the number of household moves." Importantly, Lead exposure was one of the four factors. Coulton (2020 in Cleveland found a 35% increase in adult incarceration of children who had elevated blood lead levels (≥5 ug/dL).

A further study by Nevin (2007), showed an extraordinary correlation between lead exposure and preschool blood lead levels with crime and violent crime 19 to 23 years later across nine different countries (US, UK, Canada, France, Australia, Finland, Italy, West Germany and New Zealand). **The association between lead and crime includes significant associations with the individual crimes of burglary, robbery, aggravated assault, violent and sexual assault and rape across many countries** (Nevin 2007).

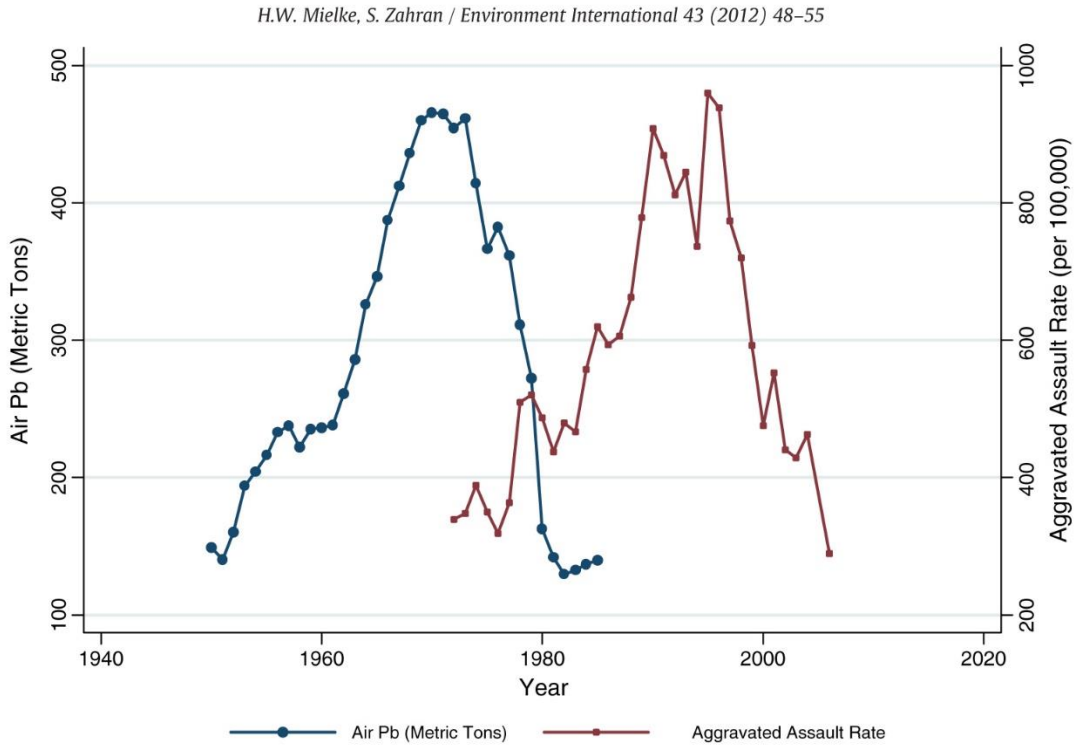


Figure 2: The aggravated assault rate in New Orleans (as reported to the FBI by the New Orleans police) (purple line) in comparison to the air lead emissions in New Orleans 22 years previously (blue line). The figure shows a remarkable concurrence between the two and is consistent with a critical role of lead emissions early in life in contributing to crime later (Mielke and Zahran 2012).

Mielke and Zahran (2012) studied lead contamination in six US cities (Chicago, Indianapolis, Minneapolis, San Diego, Atlanta and New Orleans) and at the neighbourhood level in New Orleans. In New Orleans (Figure 1), the air lead emissions rose from a base of 130 metric tons per year in 1950 to a peak of about 470 metric tons per year in the mid-1970s and then decreased to 120 metric tons by 1982. In parallel the aggravated assault rate rose from about 320 per 100,000 in 1975 to 960 per 100,000 in 1997 and fell to 280 per 100,000 by 2007. This was an increase of more than 6,000

aggravated assaults per million population per year from the base to the peak level, all related to the increased lead emissions. Overall, **across all six cities, lead emissions explained and predicted up to 90% of the variation in aggravated assault rates.** As Mielke and Zahran (2012) note, "such predictive power is rarely observed in social science data of this kind, particularly in statistical models with one variable."

Moving from the city level to the neighbourhood level **in New Orleans, there was a strong correlation between the release of lead into the air 22 years previously and the number of aggravated assaults for each neighbourhood.** In neighbourhoods where there was increased lead released into the air 22 years earlier, there was increased crime (see also Drum 2016). The strength of this association was strong. The likelihood it occurred by chance was one in a thousand.

Recently, (Emer et al 2020) completed a comprehensive study of the relationship of lead exposure to firearms violence in Milwaukee. The results show that, **"the proportion of firearm violence attributable to blood lead ≥5 µg/dL was 56% for perpetration and 51% for victimization."** In brief, 89,129 individuals born in Milwaukee between April 1, 1986 and December 31, 2003 were followed until December 31, 2015. All individuals had at least one blood lead test before age 6. In the follow up period, 553 committed firearms violence and 983 were victims of firearms violence. Individuals with a blood lead level of 5 ug/dL or more were found to be more than twice as likely to have committed firearms violence than those with a blood lead level of less than 5 ug/dL. There was a dose response. The likelihood of an individual committing firearms violence increased by 130% for those with a blood lead level of 5ug/dL to <10 ug/dL, 150% for those with a blood lead level of 10 ug/dL to <20 ug/dL and 180 % for those $\geq$ 20 ug/dL. Similar results were found for the likelihood that an individual would be a victim of firearm violence. Such likelihood increased by 80% for those with a blood lead level of 5 ug/dL to <10 ug/dL, by 140 % for those with a blood lead level of 10 to <20 ug/dL, and by 230% for those with a blood lead level of $\geq$ 20 ug/dL. The authors conclude, "**the possibility that over half of firearm violence among this sample might be due to lead exposure suggests the potential importance of lead exposure reduction in firearm violence prevention efforts**."

Further evidence that lead exposure causes an increased likelihood of crime comes from looking at lead from various sources, and in additional studies described in detail later in this report.

Lead in gasoline and crime:

In the United States, as in other countries, the use of lead in gasoline used by vehicles increased with the expanded use of cars and trucks. Beginning in 1970, the lead content of leaded gasoline was reduced and the proportion of unleaded gasoline increased starting in 1974 until lead was eliminated from use in gasoline in 1996. **The pattern of gasoline lead use in the US from 1941-1975 explained 90% of the variation in crime rates from 1964 to 1998 (Nevin 2007).** In a related study, Reyes (2007) used evidence based on the timing of states' compliance with the Clean Air Act in the US to show that reductions in childhood lead exposure in the 1970s and 1980s accounted for more than half of the violent crime decline in the US in the 1990s.

Notably during the years with an upswing in lead use and in crime (20 years later), crime rates increased particularly in those who were younger (aged 18 and 19) and had the highest childhood lead exposure. In the later time period (when lead use and crime were declining), the decline was greatest in those under age 34, while incarceration rates actually rose for those age 34 and older (who had had the highest lead levels in childhood during this period). These results, in the latter period, are consistent with younger people growing up as lead was being eliminated from gasoline having less lead in their bodies and causing less crime, while those who were older who had grown up earlier when exposure to lead in gasoline was highest continued to have a high rate of criminal activity. These results are consistent with the strong association between lead exposure and lead levels early in life and crime in later life.

Of interest is the association, in the US, between city size, lead exposure, lead levels and crime. From 1985 to 1994, the average murder rate per 100,000 people was 33 in cities with a population over 1 million; 21 in cities of 250,000 to 1 million; and 15 in cities of 100,000-250,000. Larger cities (more than 1 million) had in the 1960s (20 years previous) air lead levels twice those of cities with populations of 250,000 to 1 million, which in turn had air lead levels 40% higher than cities of 100,000 to 250,000. Following the 1980s phase out of lead in gasoline in the US, the average 2000 to 2002 murder rates per 100,000 population were 14.7 in cities of more than 1 million; 14.6 in cities from 500,000 to 1 million; 15 in cities from 250,000 to 500,000; and 9.5 in cities of 100,000 to 250,000. The flattening of the curve relating murder rate to city size reflects the decrease and flattening of lead exposure as the use of lead in gasoline was eliminated.

Nevin attributes 90% of the 75% drop in crime in New York City from the early 1990s to 2010 to a decrease in lead exposure. Just as New York saw a big decrease in crime, there was a 58% decrease in crime in Washington, D.C.; a 70 % decrease in crime in Dallas; a 74 % decrease in crime in Newark; and a 78% decrease in crime in Los Angeles. All these correlate to decreases in exposure from lead in gasoline (Drum 2016).

The association between lead exposure and crime was matched closely in other countries as well, including Canada, Great Britain, Finland, France, Italy, West Germany and New Zealand, in spite of the fact that the timing of the phasing out and ending of lead in gasoline varied from one country to another. When Nevin was asked if he had ever found a country that did not fit the theory that lead is a major cause of crime, he said, “no, not one.” (Drum 2016).

In the 1970s and 1980s, the timing of the end of leaded gasoline varied widely among states in the United States. Jessica Reyes conducted a very careful analysis of the relationship between the timing of the ending of gasoline in states and the timing of the decrease in crime in these states. In states where consumption of leaded gasoline occurred sooner and more quickly, crime declined quickly. In states which were slower to act to reduce lead in gasoline, crime declined more slowly (Reyes 2007, Drum 2016).

In a series of studies, Nevin (2007) also provides evidence that increased criminal activity ascribed to people who are black in the United States can be explained on the basis of their living in inner city

locations with higher lead exposure to paint dust in poor housing and where lead exposure from leaded gasoline was higher. It is also possible that lead levels of children living in poverty and with inadequate diets may have a greater relative intake of lead into their bodies as adults and children with low dietary calcium will absorb more lead (Government of Canada 2013).

Overall, the work of Levin, Reyes, Mielke, Zahran and others provides a convincing case of the link between exposure to lead early in life and later criminal activity. **The conclusion is inescapable – that lead has been responsible for a significant share of the crime in many countries during the last 150 years.** As Nevin says in his conclusion, the policy implications are clear, "the association between crime and preschool lead should lead urgency to global efforts to eliminate preschool lead exposure."

Lead in water pipes and crime:

The lead to which pregnant mothers and children are exposed to can come from sources other than gasoline, including lead paint, lead from industrial facilities and lead in pipes used to transport drinking water. The association between lead in pipes carrying drinking water and crime was carefully studied by Feigenbaum and Muller (2016). They studied the relationship between cities' use of lead pipes in municipal water systems and homicide between 1921 and 1936. They found, "that cities use of lead service pipes considerably increased city-level homicide rates." The association between lead in water pipes and crime adds to the evidence supporting a link between lead exposure, blood lead levels, and crime. This study is described in more detail later (see pages 39-42).

Lead from industrial activity and crime:

A study of Stretsky and Lynch (2003) showed that high lead air levels, mostly from industrial activity in counties in the United States, was associated with a murder rate four times higher than in counties with low air lead levels.

Lead from paint and crime:

As Nevin (2007) explains, "lead used in paint accounted for almost a third of total USA lead output from 1900-1914, … The high USA per capita use of lead in early-1900s paint caused more severe USA lead paint hazards throughout the 20th Century. The lead share of USA paint pigments fell from near 100% in 1900 to 35% in the mid-1930s, but the USA did not ban residential lead paint until 1978." "The paint … had especially pervasive effects due to lead contaminated dust ingested via normal hand-to-mouth activity as children crawl."

Nevin (2000) found that there was a best-fit lag of 21 years for per capita paint lead use versus 1900-1959 murders. He summarizes, **"long term trends in paint and gasoline exposure are …strongly associated with subsequent trends in murder rates going back to 1900."**

"Since the 1980s phase out of lead in gasoline in the United States, preschool blood lead prevalence over 10 ug/dL has followed the USA trend in the prevalence of housing with dust hazards caused by interior lead paint" (Nevin 2007, Jacobs and Nevin 2006). Ingestion of lead-containing paint chips can

lead to average blood lead levels which are considerably higher (average 63 ug/dL) (McElvaine et al 1992) than from exposure to lead in gasoline.

Since many older homes still contain lead paint, Nevin (2000) further comments, “in the absence of new policy initiatives to address lead paint hazards, however, a continuing temporal association between lead exposure and crime … suggests that lead exposure could still have life-altering consequences for countless Americans born over the next several decades.” In the United States, as of 1998, 25% of homes with children under age still had significant amounts of lead-contaminated deteriorated paint, dust, or adjacent bare soil” (American Association of Pediatrics 2020).

Other Sources of lead:

A number of other sources of lead may be important. These include contaminated soil, lead batteries (about 85% of the current use of lead is in lead-acid batteries), the glazes or decorations on certain ceramics (particularly those from Mexico), children’s metal and plastic toys (especially imported toys, antique toys and toy jewelry), ammunition and at firing ranges, lead weights used in fishing, amalgams which used to be employed to fill cavities in teeth, spices (particularly turmeric), cosmetics, ayurvedic medicines, lead solder in food cans and recently in e-cigarettes (Rees, Fuller et al. 2020). As well, parents who work in industries which involve working with lead may bring contaminated dust home on their clothes inadvertently exposing their children. Lead-acid batteries are used “in traditional and electric vehicles, back-up power supplies for consumers, critical systems such as hospitals and telecommunications, and for green technologies, such as photovoltaic and wind turbine energy storage” (Rees and Fuller 2020). Examples of folk remedies and cosmetics which may contain lead include Ba-baw-san (a Chinese herbal remedy), Daw Rway (Thailand and Myanmar), Greta and Azarcon (traditional Hispanic medicines), Ghasard (an Indian fold medicine) and Sindoor (a traditional Indian cosmetic powder).

Further insights into the effect of lead on brain function, juvenile delinquency and crime:

While there is evidence that brain damage in general is associated with crime (Raine et al, 1998), the impact of lead appears to be on brain functions that are critically related to functions like aggressivity and impulse control. These may be specifically associated with crime. It has been suggested that, “incomplete development of the blood-brain barrier in fetuses and in very young children increases the risk of lead’s entry into the developing nervous system,” and that this may be one reason why the brain is so susceptible to the effect of lead during fetal life and in early childhood years (Agency for Toxic Substances and Disease Registry 2000). The impact of lead on crime may be mediated in part by the effect of lead to increase the likelihood of substance abuse as described earlier. The impact of poverty on crime may be in part the result of poverty being associated with an increased likelihood of high blood lead levels, as discussed in more detail later. Those who develop high lead levels in part because of poverty, will in turn be affected by having an increased likelihood of learning difficulties, school absences, dropping out of school, being unemployed and having children who in turn are affected by the high lead burden of the mother. In this way, the action of lead is intergenerational in that high lead levels in a mother not only impacts the mother but also the child. Thus, lead does not act in isolation.

Indeed, lead may be a critical link in a vicious intergenerational cycle of poverty, substance abuse, mental illness and crime. If we can address and reduce the burden of lead, perhaps we can have a major impact not only on crime, but also to reduce substance abuse, mental illness and poverty.

Lead exposure through gasoline, water pipes, paint and industrial use in Manitoba:

If lead is a significant cause or contributor to crime in Manitoba there must be sources for lead exposure in Manitoba. This section explores the sources of lead exposure in our province.

Lead in gasoline:

As engineers increased compression to get better performance from car engines, they ran into the problem of engine knock. After trying iodine and grain alcohol to address this, they decided on tetraethyl lead which was easy, inexpensive and patentable. Lead was dangerous from the beginning. Thomas Midgley, the researcher at GM's Delco division who found tetraethyl lead, became too ill from lead poisoning to attend the ceremony introducing it. At the plant that made the additive, 15 workers died and 40 became ill within a year (McIntosh 2019). Lead was eliminated in gasoline, depending on the state, between 1976 and 1986 in the United States. It was eliminated in gasoline in Manitoba and Canada in 1990. While there may at one point have been higher concentrations of lead in soil along busy roads, the impact of this may be less today. However, there remains significant soil contamination along heavily used roadways and this may, in some areas, contribute significantly to the lead exposure of people in Winnipeg (Intrinsik 2019).

Lead in paint:

In Canada, "Nearly all homes built before 1950 and about 75% of homes built before 1978, contain lead based paint. Some paints manufactured before 1950, contained as much as 50% lead by weight" (Canadian Home Inspection Services 2020). While lead in paint for interior surfaces of homes ended in 1978, lead in paint continued for exterior surfaces up until 1990. For homes built before 1978, there are still concerns with regard to small children chewing on paint chips or picking up contaminated dust inside homes and this also applies for homes built until 1990 for the dust and soil outside homes. Concern also exists for those working in the home renovation business who are removing paint which was applied to interior surfaces before 1978 or to exterior surfaces before 1990. It remains to be determined how much of a problem the lead in older paint is today, but it is likely significant in older homes. More information may be available when children or adults with high blood lead levels are carefully assessed to determine the source of the high lead levels in children and adults in Manitoba. Lead was eliminated in paint in the United States in 1978. It is also to be noted that pica, (a compulsive eating disorder in which children eat non-food items such as dirt) eating paint chips and other non-nutritional items, is more likely to occur in children with anemia and/or nutritional deficiencies which are more likely to occur in situations of poverty. This is an additional reason why children living in poverty may be more likely to develop high lead levels. The Canadian Home Inspection Services (2020) adds "As of September 9, 1996, new US federal regulations require sellers and landlords to provide prospective buyers and renters, disclosure about lead conditions in the home. It is our opinion that Canada will soon be introducing similar legislation."

Lead in industrial use:

Significant information exists on industrial sites in Winnipeg where there were high lead levels. High lead levels in industrial areas of Winnipeg have been known for some time, although successive NDP and Conservative governments kept much of the information in reports secret for years. A major source of lead exposure was three lead smelters which operated in Winnipeg for many years – Canada Metal Smelter, Canada Bronze Smelter and Northwest Smelting Company. Additional sites with lead contamination included scrap yards along Sutherland Ave in North Point Douglas, along rail lines and near the airport (Intrinsik 2019).

Soil surveys in 1978 and 1979 showed high lead in soils near major traffic arteries and also in three areas in Winnipeg where industrial activity has led to high lead contamination (near the St. Boniface Industrial Park; in the area near the Weston School; and in North Point Douglas). Numerous articles and reports attest to this (Wotten 1979, Krawhuk 1980, Wotten and Doern 1982, Manitoba Conservation 2010, Manitoba Sustainable Development 2018, Nicholson 2018, Hirschfield 2018, Annable 2019, Intrinsik 2019).

In the St. Boniface Industrial Area there is a scrap metal recycling plant which processed and recycled an estimated 178,500 tonnes of scrap metals in 2017. On March 13, 2019 the snow in the region of the St. Boniface Industrial Area was sampled to determine atmospheric pollution levels (Solademi and Thompson 2020). The results showed "different pollution indices, specifically contamination factor (CF), degree of contamination (DOC), and pollution load index (PLI) all registering high contamination. In more detail "The CF registered high for lead, zinc and nickel in all areas compared to background levels, but the highest levels were nearby to the scrap metal shredder. The DOC values showed that the industrial contamination is nearly five times greater than that for the road or commercial areas and almost 20 times greater compared to the residential/parkland. With PLI levels above 1 considered contaminated, the shredder (4.1), roadside (2.2) and commercial areas [which includes a child care facility] (1.9) were polluted but not the residential/parkland areas (0.6). These findings point to the scrap metal shredder as causing the present-day contamination of all areas studied, including residential/parkland, traffic and commercial areas.. Enforcement and enclosure of the outdoor shredder should be considered to reduce heavy metal exposure".

Despite information about the lead contamination, effective action has not yet resulted in resolving the issue and concerns remain about the impact of the historic lead contamination on people in contaminated areas and on our communities. There are two areas of specific concern – the health of children and the level of crime in our community.

Outside of Winnipeg, lead has been identified as one of the minerals present in emissions from the Hudson Bay Mining and Smelting Co. Ltd.'s smelter complex over the course of many years. Concentrations of lead in some soil samples in Flin Flon were found to be above the Canadian Council of Ministers of the Environment soil quality guidelines in 2006 (Manitoba Conservation 2007).

Lead in water pipes:

Water pipes containing lead were installed in much of the centre of Winnipeg (see Map – Figure 5). In June 2000, phosphoric acid was added to Winnipeg's water supply as a means of decreasing the leeching of lead into the drinking water of Manitobans with lead pipes. However, recent measurements of the concentration of lead in drinking water obtained in Manitoba homes showed that 20% of Winnipeg homes tested had lead levels in drinking water higher than guideline (Blunt 2019a). Officials estimate that as many as, "23,000 public or private owned properties in Winnipeg … could potentially have lead service lines." The city has provided advice to concerned homeowners to suggest that homeowners run water for five minutes before drawing water for drinking. However, this is a long time to let the water run, and the instructions are, in many ways, not precise enough. Does, for example, letting the shower run change what comes through a tap in another room? The study's authors did not actually measure the impact of letting the shower run for five minutes. There are also no details as to whether this is only needed for first thing in the morning, or whether if a person is not using the water during the day, the tap water should be run for another five minutes before drinking it at the end of the day. The recommendation is also at odds with recommendations for using water wisely in our homes, and not overusing water. In all, it appears that a filter to remove the lead might be more desirable. Although this has been put forward as an option, the province has not set any standards for ensuring high lead levels in drinking water are avoided. It is also worthwhile observing that the highest crime rates are in Downtown and Point Douglas, which corresponds to areas with lead pipes shown in Figure 3 (Bruce 2018).

There is also lead in some water pipes in Brandon, Dauphin and Portage la Prairie. (Blunt 2019b); City of Dauphin 2018, Hathaway 2019).

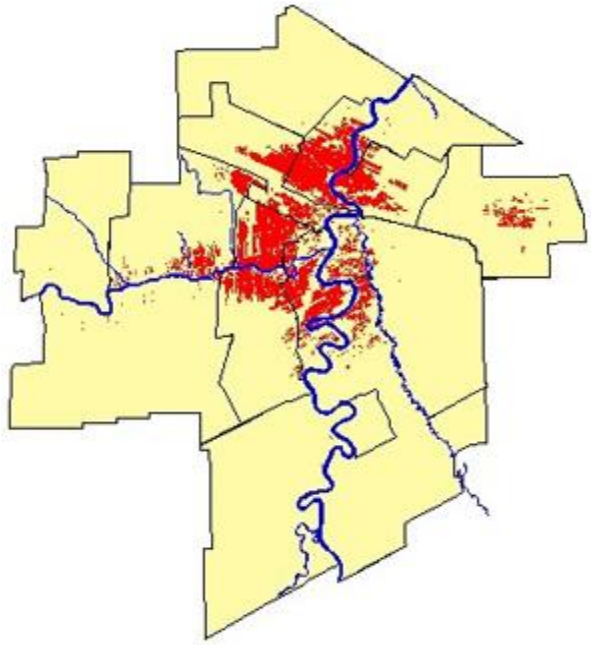


Figure 3: Map of Winnipeg with areas where there are water pipes of lead shown in red (City of Winnipeg 2020).

On an overall basis, lead levels in soil provide a way of looking at the combination of sources of local lead exposure (passed history of leaded gasoline, industrial use and outdoor use of leaded paint). A recent overview shows that there continue to be areas of Winnipeg where the soil lead concentrations are above the current Canadian Council of Ministers of the Environment residential soil quality guidelines of 149 ug/g (Intrinsik 2019). For example, 74% of soil samples from North Point Douglas and 12% of samples from residential properties in St. Boniface exceeded 165 ug/g (Intinsik 2019). The authors of this report used models to predict blood lead levels in North Point Douglas and predicted a geometric mean for the Neighbourhood of North Point Douglas of 4.7 ug/dL. If correct, this would mean nearly half of blood lead samples in the area would be at or above 5ug/dL.

Measurement of Blood Lead Levels in Manitoba:

If lead toxicity is a significant factor in crime in Manitoba, the levels of lead in the blood of some Manitobans would be expected to be high. Through a Freedom of Information request, we were able to obtain information on the results of 5191 tests measuring blood lead levels at various locations in Manitoba from 2011 to 2018.

The data was evaluated based on the consideration that any level of blood lead, at or above 0.24umol/L (5 ug/dl), is a high level of lead. This number is based in part on the following recommendation from the Canadian Pediatric Society (Canadian Pediatric Society -Buka and Herovet-Zeiber 2019). The recommendation is that, "**children found to have a blood lead level higher than 5 ug/ml (0.24 umol/L) should be investigated thoroughly and any identified exposure sources should be mitigated as soon as possible**."

In the United States, the CDC says, "As of February 22, 2018, 18 states and the District of Columbia require some action to be taken when a child's blood lead test shows at least 5 micrograms of lead per deciliter, either through explicitly adopting the five-microgram standard or through incorporating the CDC's reference level." The CDC is saying, 5 ug/dl or greater, and thus in this report we are being precautionary by including the level of 5 ug/dL or 0.24 umol/L within the high lead level group. (CDC 2020a). **The CDC specifically states that they use the 5ug/dL level as their "reference" level to indicate that this level identifies children who are exposed to lead and require case management.** The US Centers for Disease Control and Prevention (1991) also made clear that it is their view, based on substantial evidence that there is no lower blood lead threshold for IQ losses (see also Schwartz 1994, Canfield et al 2003). The Government of Canada (2020) says, "effects associated with BLLs below 10 µg/dL, down to 1-2 µg/dL, have been reported in the health effects database and include neurodevelopmental, neurodegenerative, cardiovascular, renal, and reproductive effects." These statements provide further rationale for the choice of 5 ug/dL as the lowest point to include as a "high lead" level in this report.

In this report, it is recognized that levels of lead in adults might be acceptable at higher than 5 ug/dL. However, levels of 5 ug/dL and below in adults aged 20-39 have been associated with an increase in major depressive disorders and panic disorders. Bouchard et al (2009) found that, "compared with persons with a blood lead level below 0.7 µg/dL (the lowest quintile of blood lead in our study population), those with a level greater than 2.1 µg/dL (the highest quintile) had a 2.3-fold increased risk of meeting the DSM-IV criteria for major depressive disorder, and 4.9-fold increased risk for panic disorder." Increased mortality from heart attacks and strokes has also been reported at lead levels below 10 ug/dL (0.48 umol/L) (Menke 2006). Thus, there are concerns about lead levels in adults at or below 5ug/dL as well as in children, and when all factors are considered, the choice to use 5 ug/dL of lead and above as "high" is reasonable. Further, since the lead levels available for this report through a FIPPA request were not identified as to age of person, there was a need to use one level for all samples. Thus for this report, blood lead levels of 5 ug/dL (0.24 umol/L) or more are considered high blood lead levels.

The level of blood lead which is considered of concern has been steadily lowered as increasingly studies have shown that smaller and smaller levels of lead are associated with adverse impacts on humans, particularly in utero and in the early childhood years. For example, in the United States in 1970, the level of concern for blood lead levels was 40 ug/dl. It was lowered to 30 ug/dl in 1975; 25 ug/dl in1985; 10 ug/dl in 1990; and to 5 ug/dl in 2012. While it is generally recognized now that no level of lead may be considered safe, the level of 5 ug/dl (0.24 umol/L) and above are now generally recognized as levels where intervention is needed.

Based on the graphs shown in Figures 1 and 29 to 33 and data from other similar studies it could be argued that the choice of 5 ug/dL may be too high, and that 2 or 3 ug/dL should be used instead of 5 ug/dL. In one recent study in Winnipeg, 2 ug/dL was chosen as the level of concern for children (Intrinsik 2019). While we are likely in the future to move to lower levels, as the CDC and other sources (Rees and Ruller 2020) currently use 5 ug/dL, this report uses 5 ug/dL and above as high.

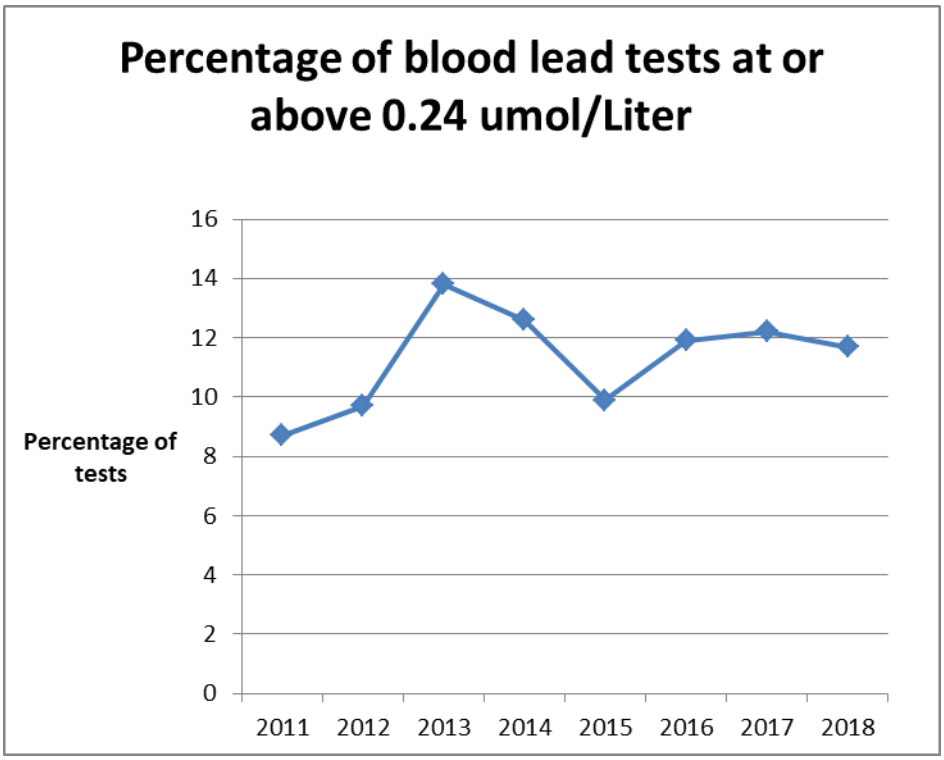


Figure 4: The percentage of blood lead tests which showed a level of 0.24 umol/L (5ug/dL) or higher from 2011 to 2018 (Data from the Government of Manitoba obtained through a Freedom of Information request)

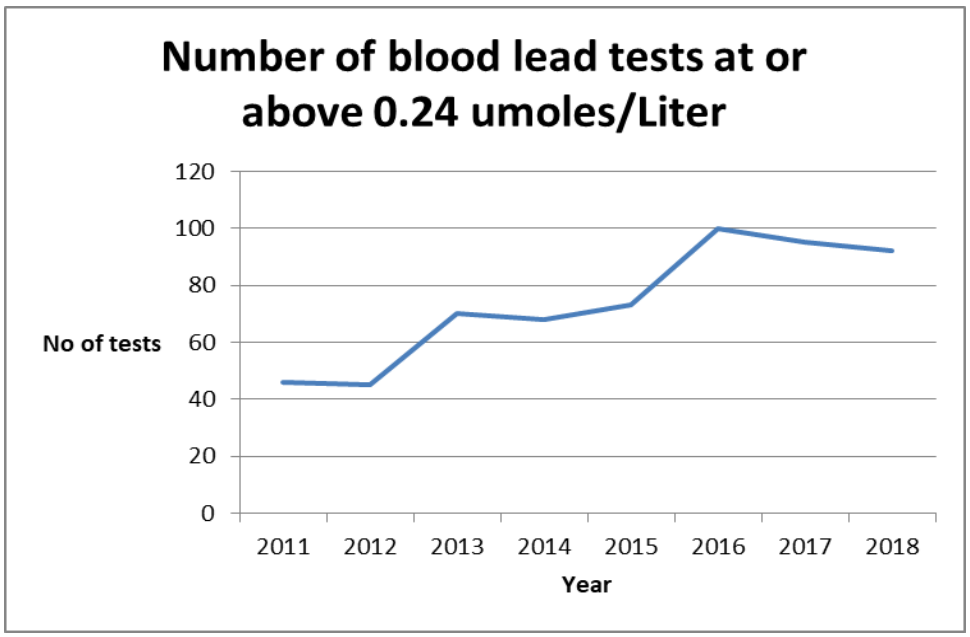


Figure 5: The total number of blood tests done in Manitoba from 2011 to 2018 which showed a blood lead level at or above 0.24 umoles/L (5 ug/dL) (Data from the Government of Manitoba obtained through a freedom of information request)

The results show that about 12% of blood lead tests in Manitoba had values of 0.24 umol/L or greater in 2016-2018. This is up from just over 8% in 2011 (Figure 4). Since the number of tests rose substantially from 2011 to 2018, the total number of high lead levels also rose substantially - essentially doubling from an average of 46 in 2011 and 2012 to an average of 96 from 2016-2018 (Figure 5). The number of high lead levels in tests shows that there continues to be a significant number of Manitobans who are sufficiently exposed to lead to have high lead levels. Since we do not have information on the ages of individuals tested it is not clear whether this is primarily older individuals who tested at high levels, or whether positive tests occurred at all ages. Because the measurement of lead levels is generally considered to be of greater concern in children it is possible that more of the testing may have been done on children. If this is the case, then the results are even more concerning as they indicate more recent exposure.

Some information on the geographic distribution is available. However, since the data available in the freedom of information request provided only the location where the test was done, the geographic information cannot be considered to be precise. Nevertheless, for rural areas, more of the positive tests were from communities known to have lead in their water pipes or where there was a greater level of industrial activity. Sites where there were higher proportions of the tests which showed high lead levels included: Pine Falls 50% (30 tests); Selkirk 21 % (111 tests); Dauphin 19% (80 tests); Flin Flon 18% (33 tests); and Portage la Prairie 17% (47 tests). Communities where the proportion of high tests was lower than most of the province included: De Salaberry 6% (31); Steinbach 5% (55); Morden/Winkler 4% (23); Beausejour 0% (71); and Gimli/Arborg 0% (57). Of the communities with a higher proportion of high lead

tests, Dauphin and Portage la Prairie are known to have a proportion of their water service lines made of lead, and Flin Flon is known to have exposure as a result of lead emissions from their smelter which operated for many years (City of Dauphin 2018, Hathaway 2019, Manitoba Conservation 2007). Selkirk has a scrap metal processing and steel production industry, but it is not known at this time whether there are lead emissions. The source of lead exposure in Pine Falls remains to be determined.

In Winnipeg, tests done at the Health Sciences Centre 11.5% (1982 tests) or St. Boniface Hospital 11.6% (2222 tests) were similar. The Grace Hospital 3% (62) on the west end, and Victoria Hospital in South Winnipeg 0% (46) were comparatively low consistent with the fact that these areas have more newer homes which do not have lead in their water pipes or lead in their paint. The pooled average of tests at Concordia and Seven Oaks 6.7% (30) was intermediate, possibly reflecting the fact that only part of their catchment areas included homes served by lead water pipes.

In summary, the evidence from blood lead levels establishes that Manitoba has a serious problem with too many people having high blood lead levels. The data should be used with caution until more information on the age and location of individuals with high blood lead levels is available, and until there is an investigation of the sources of the lead exposure in these individuals. The information from the analysis which was done is, however, sufficient to warrant urgent additional evaluation of blood lead levels in people in Manitoba, including Winnipeg and rural communities with a high proportion of high lead levels.

Crime in Winnipeg and Manitoba:

Winnipeg and Manitoba have been identified as crime hot spots in Canada.

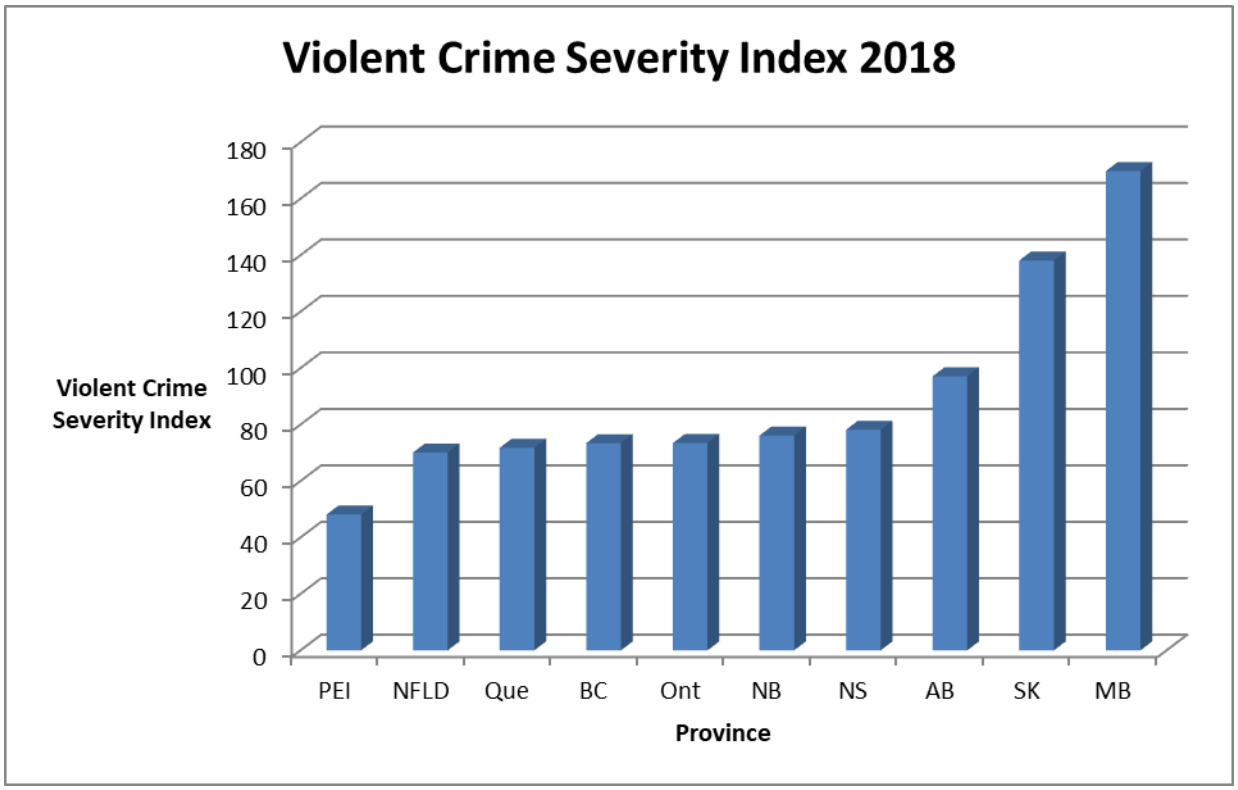


Figure 6: The comparative violent crime severity index in Manitoba compared to other provinces. (Data from Statistics Canada).

Manitoba is the highest of all provinces in terms of violent crime severity. Indeed, Manitoba has more than double the average severity of violent crime compared to the rest of Canada (Figure 6).

Saskatchewan has had a level of violent crime severity which approaches that of Manitoba, while Alberta and British Columbia are much lower (Figure 7). However, in recent years, Manitoba has moved substantially higher than Saskatchewan (Figure 8). As well as violent crime, robbery is very high in Manitoba at 156 per 100,000 compared to Canada with a rate of 60 per 100,000 nationally (Wikipedia 2020).

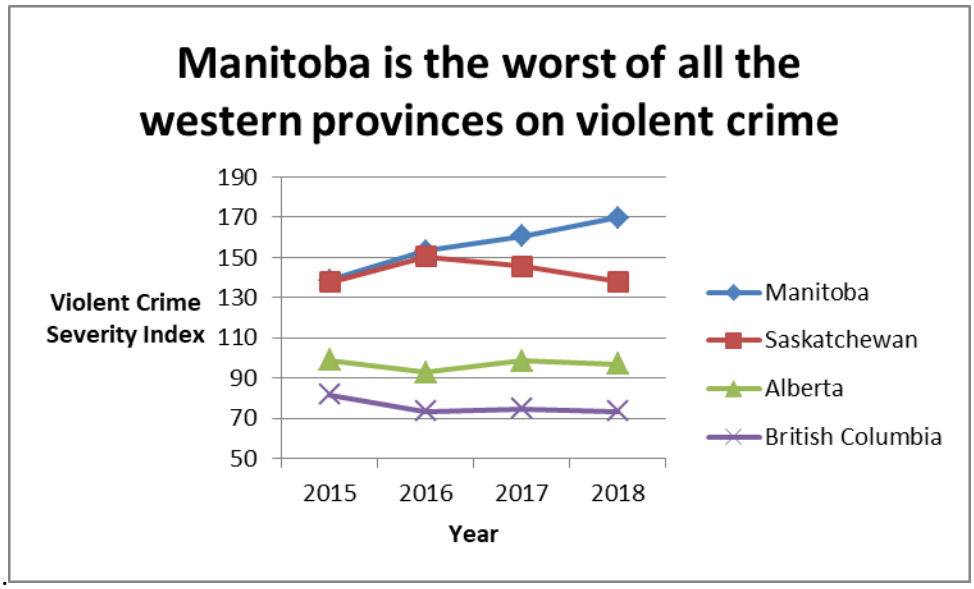


Figure 7: A comparison of the violent crime severity index in the western provinces of Canada. Data from Statistics Canada.

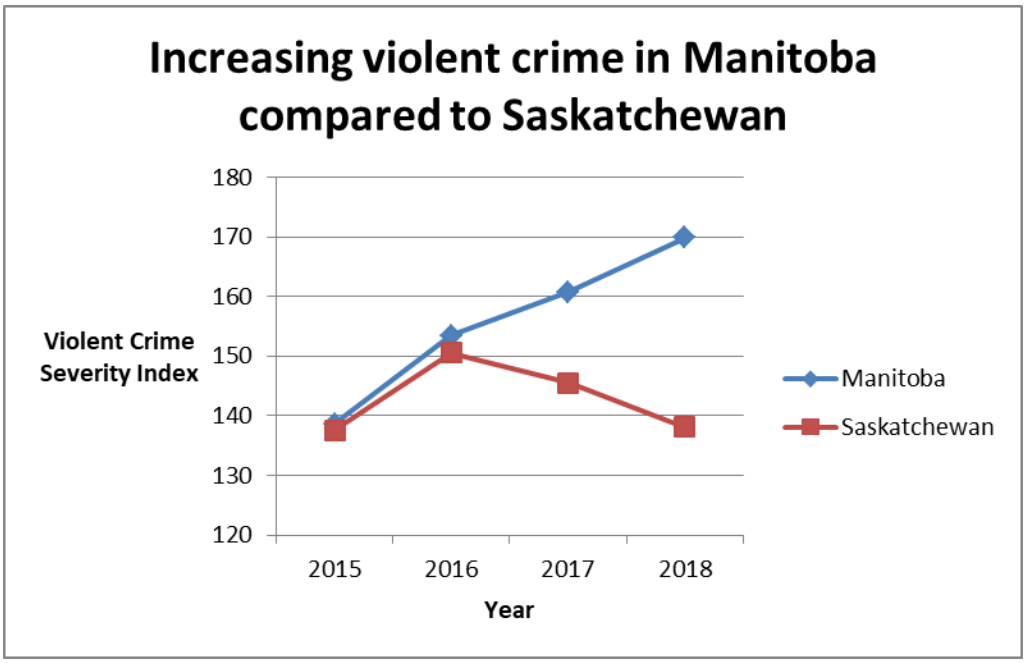


Figure 8: While Manitoba's violent crime has increased since 2016, crime in Saskatchewan has decreased (data from Statistics Canada).

Taken in the context of what is happening in the rest of Canada, the increased level of violent crime in Manitoba is extraordinary. It suggests there is something in Manitoba that is causing the very high level of violent crime. Many factors have been suggested as causes, but not one has been proven as the cause. There has been a tendency to put all the blame on those who commit crimes - who are disproportionately Indigenous people in our province. It is time to look carefully at addressing the

underlying causes of crime and as part of this effort to look at lead as a fundamental cause, major contributor or underpinning to crime in Manitoba (for more see Appendix 4).

Manitoba is higher than other provinces in both intimate partner violence and in sexual assault.

In 2017, Manitoba had a police reported rate of intimate partner violence of 599 victims per 100,000 population age 15 and over. This compared to a rate of 313 for all of Canada. In the same year, Manitoba had a police reported rate of non-intimate partner violence of 1,436 victims per 100,000 population while the rate for all of Canada was much lower – 721 per 100,000 (Statistics Canada – 1). In 2016, Manitoba recorded the highest rate of police-reported sexual assault among the Canadian provinces, with 109 incidents per 100,000 population - almost twice the national rate of 58 (Manitoba Women's Advisory Council 2018). Following the #MeToo movement, the annualized rates increased to 132 for Manitoba, and to 74 for Canada for October 2017 to December 2017 (Statistics Canada – 2).

Evidence which suggests that lead exposure is a contributing factor to crime in Manitoba:

1) Evidence from studies of children – conduct disorder – and ADHD – in areas with high lead exposure:

Specific studies in Winnipeg in areas where high lead levels have been reported:

Concerns have been raised about the health of children in areas of Winnipeg where high lead levels have been reported in the environment as a result of industrial and other exposure (Wotten 1979; Krawchuk 1980; Wotten and Coern 1982; Manitoba Conservation 2010; Hirshfield 2018; Nicholson 2018; Annable 2019; Manitoba Sustainable Development 2019, Intrinsik 2019). This includes near the St. Boniface Industrial Park, in Weston, and in North Point Douglas in Winnipeg, areas where soil lead levels have been found to be high (Intrinsik 2019). As an example in North Point Douglas 74% of soil samples exceeded 165 ug/g.

The use of medications to treat behavioural problems like Attention Deficit Hyperactivity Disorder (ADHD) is one measure of the extent of behavioural issues among children and youth. Medications prescribed are easier to measure using the existing databases, than individual diagnoses of ADHD. For the area near the St. Boniface Industrial Park, there is an increased incidence of the use of anti-psychotic and psychostimulant medications compared to the rest of Winnipeg as shown in Figures 9 and 10. I raised this concern in the Manitoba Legislature in December 2018 and asked the government to look into the health of people in this area (Appendix 12).

Use of Anti-psychotic and psychostimulant medications in St. Boniface:

Figure 9 shows the number of prescriptions for anti-psychotic medications for children and youth in the area near the St. Boniface Industrial Park in 2017/2018. Figure 10 shows the number of prescriptions for psychostimulant drugs (often used to treat ADHD) in the area near the St. Boniface Industrial Park. These data are consistent with an increased diagnosis of ADHD in this area, however further research is needed.

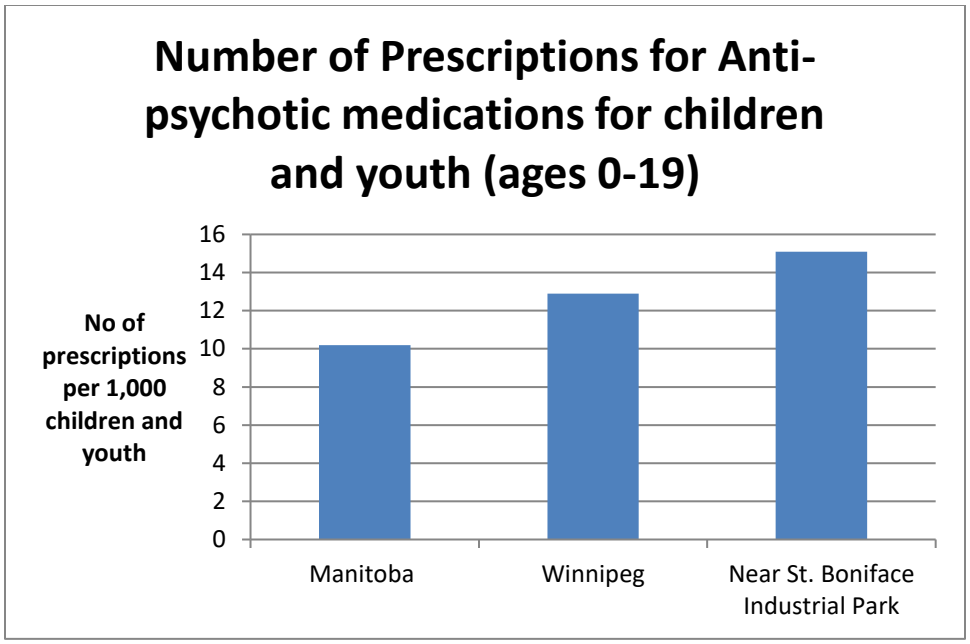


Figure 9: Anti-psychotic medications used in children and youth aged 0-19 in the area within postal codes near the St. Boniface Industrial Park in 2017/2018. The increased numbers for children and youth near the St. Boniface Industrial Park are significant ($p<0.05$) (Data from the Government of Manitoba through a Freedom on Information request).

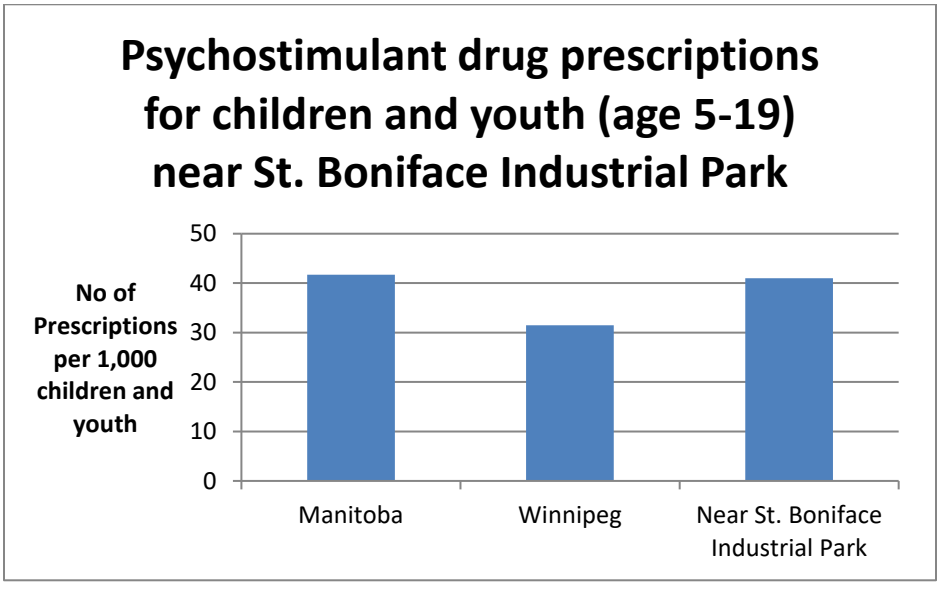


Figure 10: Psychostimulant medications for children and youth near the St. Boniface Industrial Park compared to Winnipeg and Manitoba. The Difference between the prescriptions near the St. Boniface Industrial Park and the rest of Winnipeg is significant ($p<0.05$). The reason for the higher number of prescriptions in rural Manitoba than Winnipeg is not clear, but is not likely related to lead. (Data from the Government of Manitoba through a Freedom of Information request).

In a different but related note, looking directly at the incidence of varied measures of the extent of behavioural disorders and mental illness in the Weston and North Point Douglas areas, several conditions were found to be higher in these areas compared to the rest of Winnipeg.

Incidence of conduct disorder; substance abuse; attempted suicide; mood and anxiety disorders in Weston and North Point Douglas:

For children and youth living in postal code areas which include Weston and North Point Douglas from 2013 to 2017, there was an increased incidence of certain brain and mental health conditions. This included conduct disorder, substance abuse, attempted suicide as well as mood and anxiety disorders.

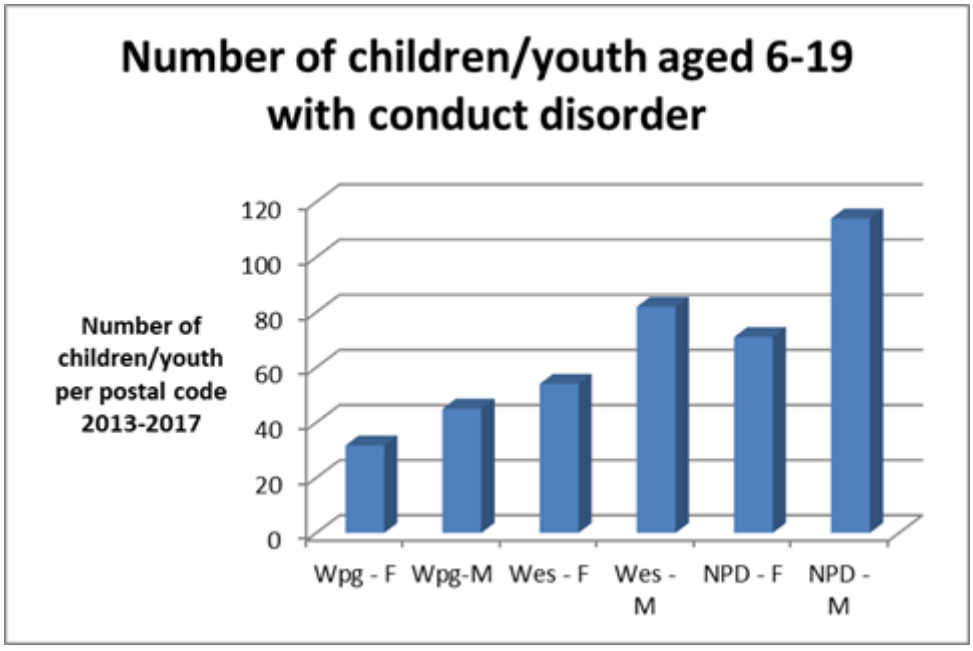


Figure 11: Increased incidence of conduct disorder in children and youth living in the Weston area and in North Point Douglas from 2013 to 2017 (Data from the Government of Manitoba obtained through a Freedom of Information request).

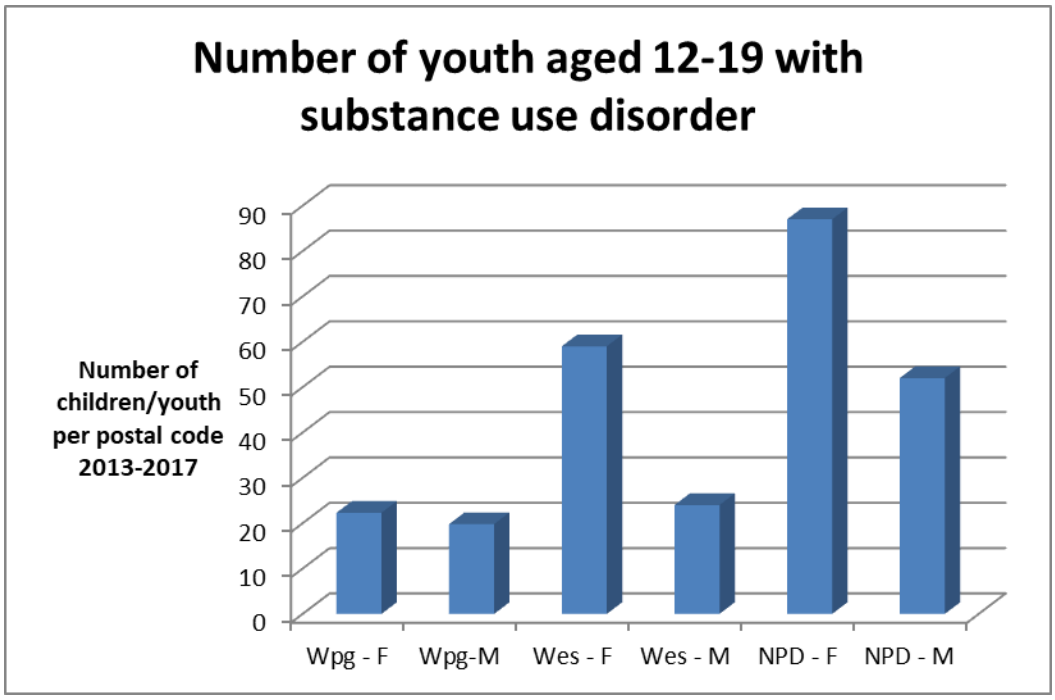


Figure 12: An increase in substance use disorder in female children and youth aged 12 -19 years of age in Weston and North Point Douglas from 2013 to 2017. Among male children and youth, the increase was only seen in North Point Douglas (Data from the Government of Manitoba obtained through a Freedom of Information request).

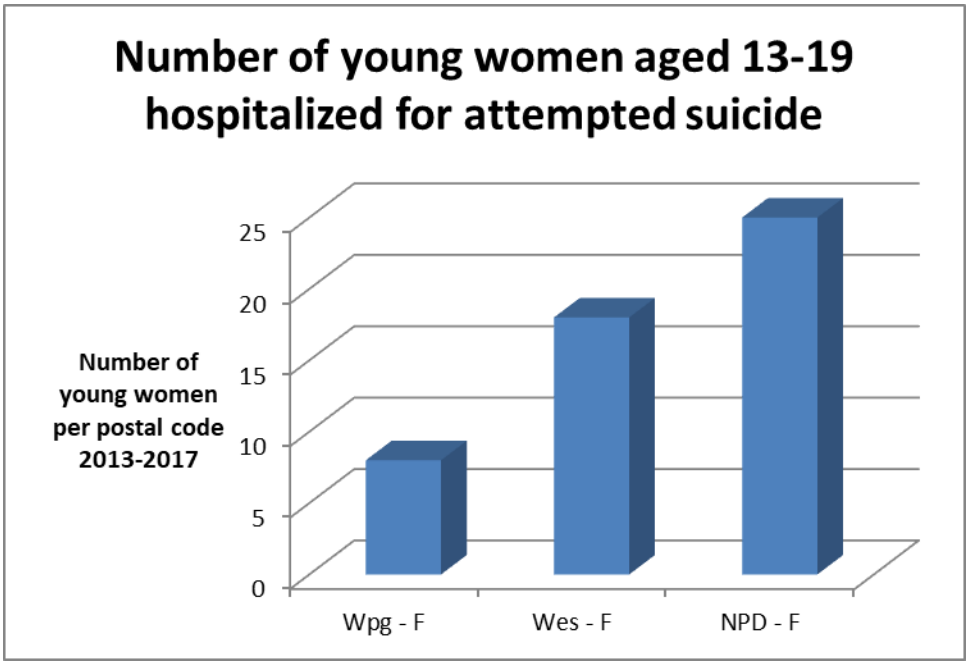


Figure 13: An increased number of young women aged 13 – 19 years of age from Weston and North Point Douglas were hospitalized for attempted suicide between 2013 and 2017 (Data from the Government of Manitoba obtained through a Freedom of Information request).

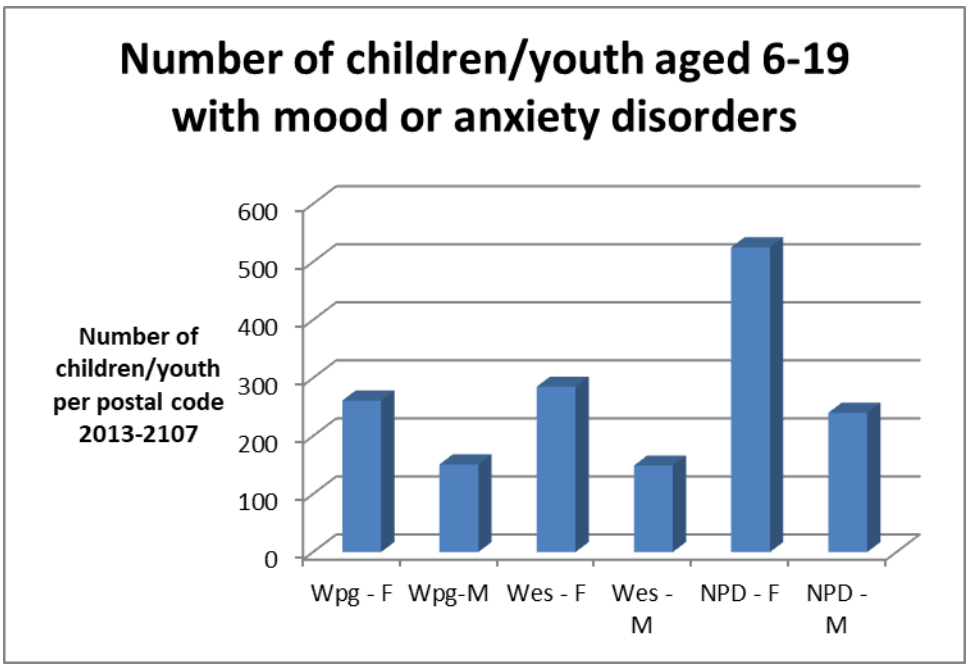


Figure 14: An increase in the number of children and youth with mood and anxiety disorders in North Point Douglas but not in the Weston area from 2013 to 2017 (data from the Government of Manitoba obtained through a Freedom of Information request).

The Figures 11-14 show that there are valid concerns about the brain health of children in three areas in Winnipeg, near the St. Boniface Industrial Park, in Weston and in North Point Douglas.

2) Evidence from the incidence of crime in Winnipeg and in rural areas – where there are increased or decreased numbers of high blood lead levels.

As shown in the maps (Figures 15-17) from the Winnipeg Police Service Crime Maps (2020), areas of higher crime are generally in areas where there are lead service water pipes. This is particularly true for violent crime and crime under the Controlled Drug and Substances Act. These are also areas where there are more likely to be homes built before 1960 (Fitzgerald et al 2004), and thus are areas with homes which are more likely to have lead paint. These findings are consistent with the concept that crime and lead exposure are related.

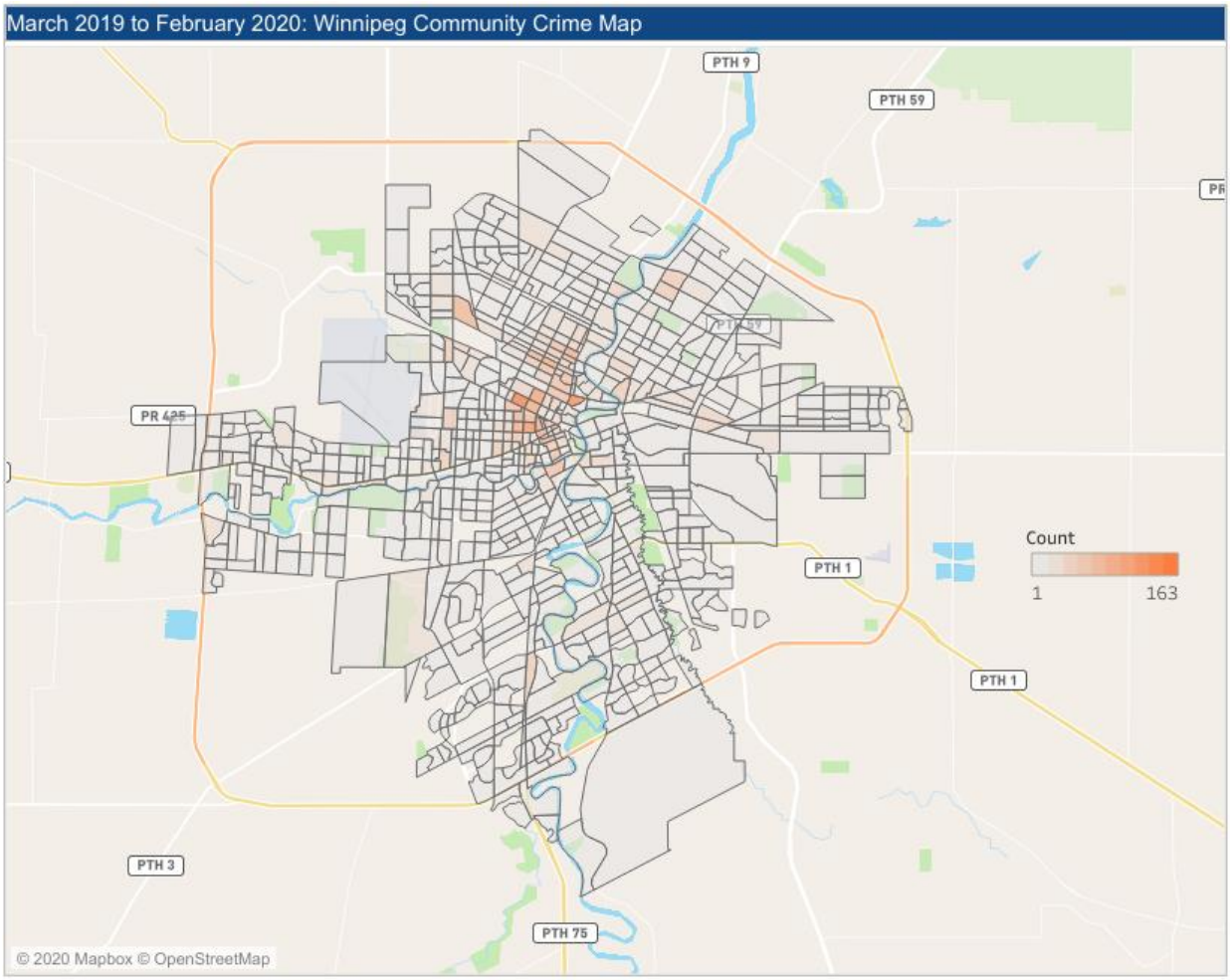


Figure 15: Distribution of violent crime in Winnipeg March 2019 to February 2020 (map from the City of Winnipeg web site).

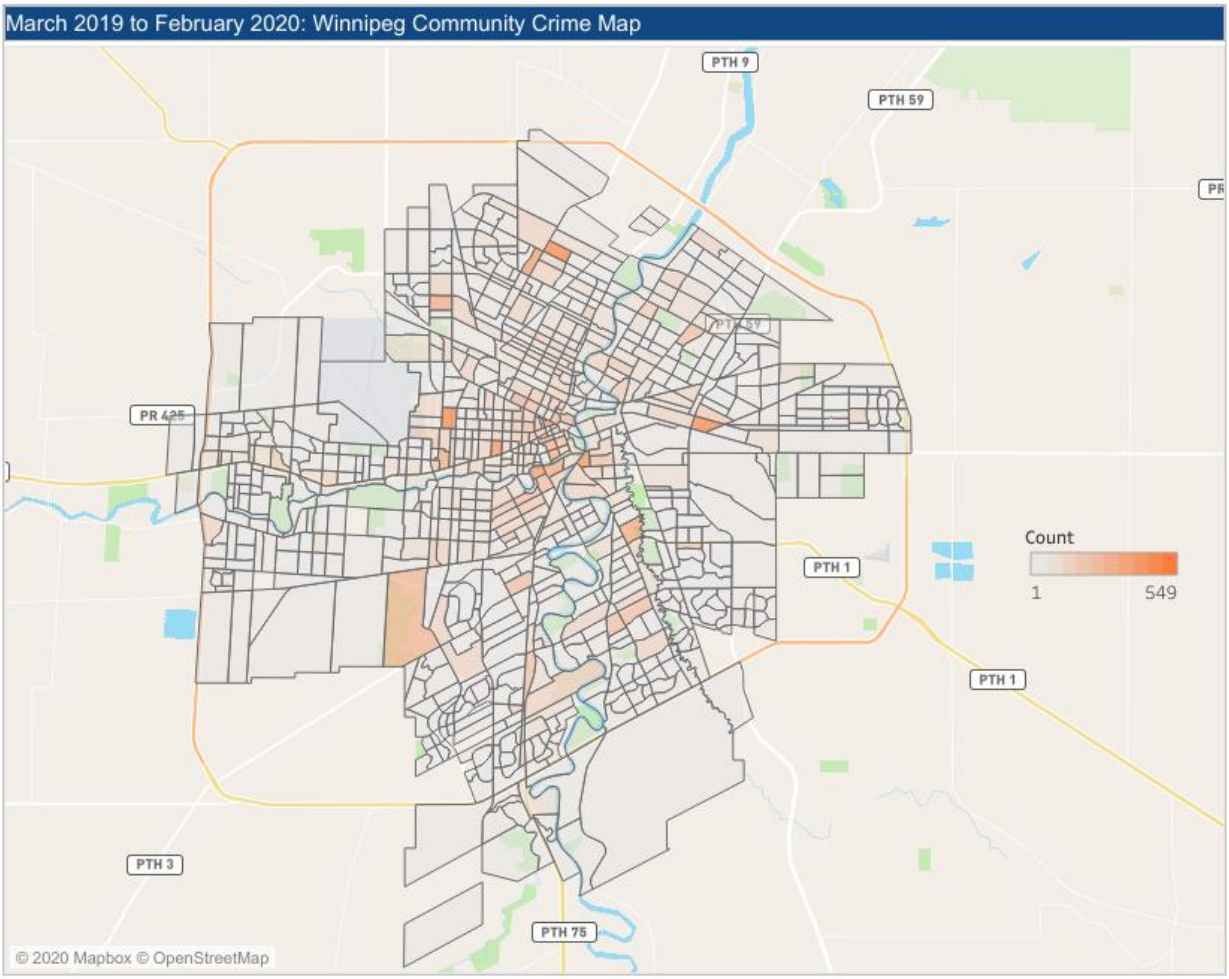


Figure 16: Distribution of Property Crime in Winnipeg March 2019 to February 2020 (Data from the City of Winnipeg web site).

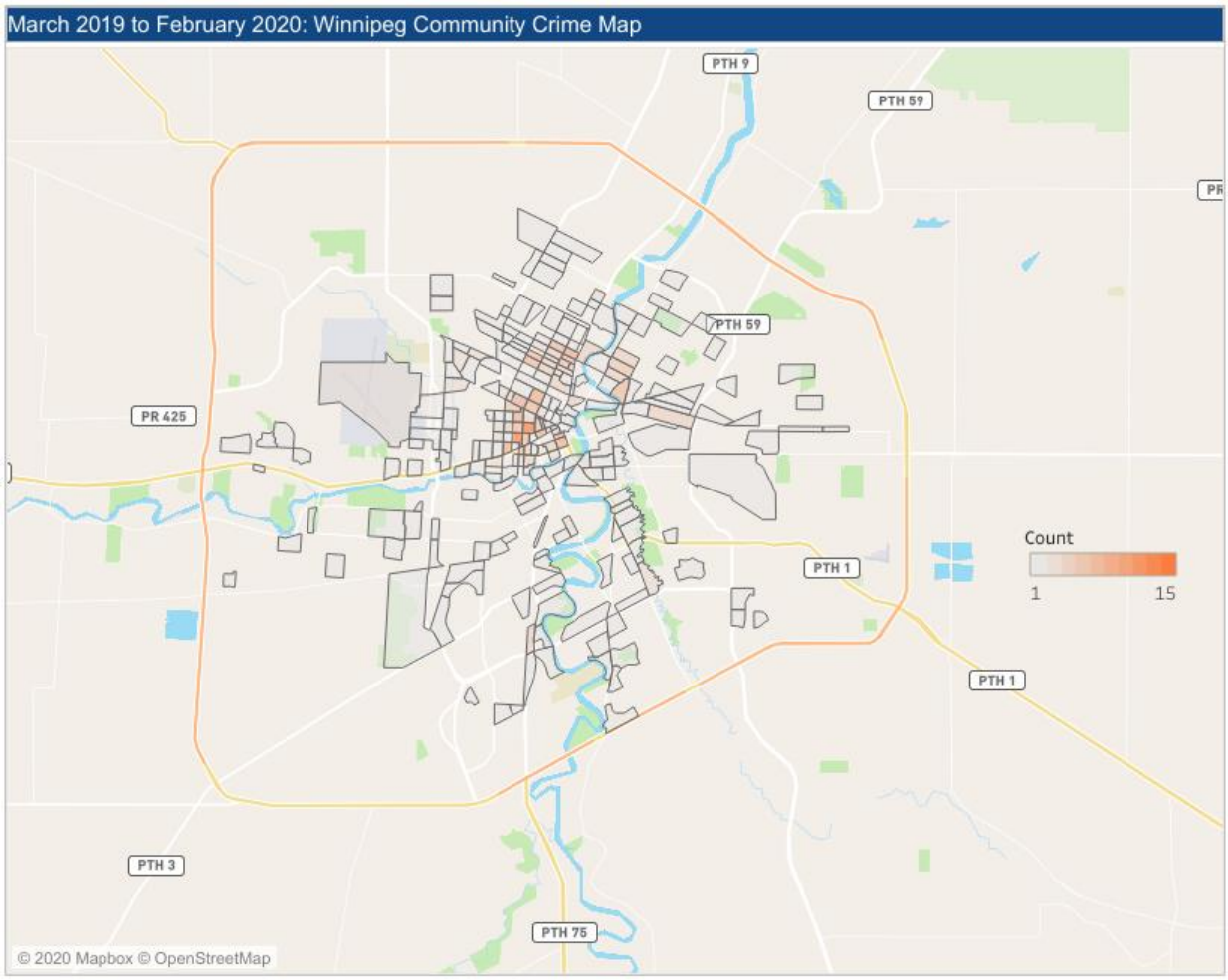


Figure 17: Distribution of Crimes under the Controlled Drugs and Substances Act from March 2019 to February 2020 (data from the City of Winnipeg web site).

Similarly in rural areas, Portage la Prairie and Selkirk - two communities with high proportions of blood lead tests being high - are recognized to have high crime rates. Portage la Prairie has the 5th highest crime severity index for communities over 10,000 in Canada; and the 3rd highest violent crime severity index for 2018 (Dumont 2019); Selkirk was 12th highest in 2017 (Macleans 2018). Crime rates in other communities with a higher proportion of high blood lead levels including Flin Flon, Powerview/Pine Falls and Dauphin were also above the provincial average. Communities with a lower proportion of high blood lead levels including Steinbach, Gimli, Morden and Winkler were below the provincial average in crime (Statistics Canada 2020). These findings are consistent with an association between lead exposure and crime. However, none of the data provided allows us to determine what proportion of violent crime in Manitoba might be due to lead exposure (Appendix 3).

The influence of Nutrition on Lead Absorption and on Blood Lead Levels:

Diet has a major impact on the absorption of lead. This is particularly true of calcium in the diet. Increased intake of calcium has been shown to be associated with a decreased absorption of lead in the gastrointestinal tract (Ziegler et al 1978; Mahaffey et al 1986). Addition of phosphorous and calcium was found to further decrease lead intake (Heard and Chamberlain 1982). Magnesium may also contribute to a decrease in lead absorption (Baltrop and Khoo 1975). With neither calcium nor phosphorous given with lead, the uptake of the lead was 63%. When both calcium and phosphorous were added together with the lead, the uptake of the lead was reduced to 10.6%. Evidence suggests lead competes for calcium and phosphorus for common transport mechanisms in the gut (Blake and Mann 1983). Milk, which contains calcium and phosphorous, has also been found to reduce absorption of lead (Blake and Mann 1983). As Goyer (1997) states, "**the importance of adequate dietary calcium in the prevention of childhood lead toxicity is now well accepted, and children at risk are provided calcium supplements in state and city led prevention programs**."

It is also very important to pay attention to nutrition during pregnancy. During pregnancy, there is an extra demand for calcium, and the body will respond, if there is not sufficient calcium in the diet, by taking calcium from bones. Lead stored in bones will be removed at the same time as the calcium, and thus with inadequate intake of calcium during pregnancy, the likelihood of increased blood lead levels in the mother and in the developing fetus is increased. The same may occur during periods when the body has extra demands for calcium, as can happen after an injury which includes a broken bone with more calcium being needed to heal the bone.

"Iron deficient individuals absorb two to three times more lead than individuals with adequate levels of blood iron. Iron and lead interact and compete in heme synthesis [heme is an important part of hemoglobin the protein in red blood cells which binds and carries oxygen in the blood so it can be transported from the lungs to the tissues]. Even slight decreases in hematocrit [the red blood cell fraction of blood] allow increased lead absorption" (Wisconsin Department of Health Sciences (2020). It is critical to prevent iron deficiency anemia in particular because there is strong evidence that iron supplements are not effective at reducing lead levels once exposure has occurred. "**Because iron deficiency is a common nutritional problem among the same children at risk for lead toxicity, it is now a general practice to supplement the diets of these children with iron as well as calcium**" (Goyer 1997). Consistent with the above, **the Centres for Disease Control guidelines recommends adequate dietary calcium and iron as measures to prevent lead toxicity**. The Wisconsin Department of Health says the relation of iron deficiency and high lead levels is such that "All children with blood lead levels $\geq$ 5 ug/dL should be evaluated for iron deficiency." And, "If iron deficiency is diagnosed treatment should begin along with treatment of the lead exposure."

Zinc deficiency can also enhance lead absorption (Goyer 1995). Malnourished children have been found to have levels of calcium, iron and zinc one to two-fold lower when compared to well-nourished

children. They may be at increased risk of lead toxicity and indeed this sample of malnourished children had lead levels which were twice those of well-nourished children (Talpur et al 2018).

The Wisconsin Department of Health also recommends that children at risk of lead toxicity should eat regular meals and snacks as stomachs that are full are less able to absorb lead. Further the Department suggests that children at risk should have diets rich in vitamin C as this vitamin can enhance iron absorption and may decrease the absorption of lead.

Vitamin D is important from a nutritional perspective. Summer seasonal elevations in blood lead levels have been related to vitamin D increasing lead absorption (Kemp 2007). However, if dietary calcium and phosphorous are high, and iron is adequate (this decreases lead absorption), it is possible that the vitamin D effect may favour calcium uptake so that lead levels are not increased and may even be lowered (Farias 1996).

Other nutrients including thiamine (vitamin B1) and folic acid may also be important from a nutritional perspective as low levels of each of these have been associated with higher blood lead levels (Lee at al 2005).

Poverty and Lead:

1) Lead exposure as a cause of poverty

It is very likely that lead exposure, which causes and contributes to learning disabilities and impaired cognitive function, low IQ; mental illness and addictions; is a cause of, or contributor to, people living in poverty. Consistent with this, the presence of learning disabilities, impaired cognitive function, low IQ, mental illness and addictions are all themselves associated with poverty.

2) Poverty as a contributor to increased lead toxicity

Poverty can itself contribute to making it more likely that an individual is exposed to lead and experiences lead toxicity. As Shonkoff and Phillips (2000) say, "lead poisoning continues to pose a threat to the healthy development of children, and disproportionately to low-income children of color living in central cities. … **poor children are disproportionately at risk for exposure to lead.**" This was looked into by Sargent et al (1995) who found, "the odds for having elevated levels of lead were nearly 9 times above average in communities in which 20 percent of the children under age 5 were living in poverty; 5.5 times higher if the community was densely populated; and 8 times higher than average if more than 10 percent of the community received public assistance (Shonkoff and Phillips 2000). Studies in the United States and particularly in Minnesota and Louisiana have also reported that poverty, residence in central cities and old housing stock considerably elevated the risk of high levels of lead in childrens' blood (Brody et al 1994, Nordin et al 1998, Mielke et al 1997). As well as individuals who are poor being more likely to be exposed to lead, nutritional factors associated with poverty can have an influence on lead absorption and lead toxicity. As described previously, and more extensively below, deficiencies in calcium, iron, zinc, phosphorous and vitamin D may be associated with substantial increases in lead absorption and blood lead levels. In addition, a study in rats showed that, "lead-treated rats in deprived environments exhibited spatial learning deficits and other markers of neurotoxic exposure, while the lead-treated rats in enriched environments showed smaller deficits in spatial learning" (Troesken 2006). This suggests that lead-related deficits may be exacerbated in a deprived environment as is more likely to occur with a child in a family living in poverty. These studies thus provide evidence for a link between poverty and an increased blood lead level. The reasons for this link are multiple including:

1) Children living in low income areas are more likely to be exposed to lead for the following reasons:

   a) Low income areas are often associated with older housing which has lead paint.
   b) Low income areas often have more crowded living conditions which are associated with more paint dust in the home.
   c) Low income areas are often found in the center of a city where the history of exposure to lead in gasoline was higher and where lead contamination of the soil is higher.
   d) Low income areas are more likely to be associated with a region of the city which is older and which has lead in the water pipes.
   e) Low income areas are more likely to be near heavy industry where lead contamination is higher.

2) Children living in poverty are more likely to experience nutritional deficiencies and anemia, both of which are associated with higher blood lead levels due to increased lead absorption or retention.

a) Children with anemia have higher rates of lead absorption and higher blood lead levels (Hegazy et al 2010). This increased lead absorption is sufficient to give significantly higher blood lead levels.
b) Children with lower calcium, iron, vitamin D and phosphorous in their diets show increased blood lead levels, probably related to increased lead absorption or retention (Sorrell and Rosen 1977, Levander 1979). Of particular significance is the finding that increased consumption of milk containing calcium is associated with lower blood lead levels. As an example, a study in Mexico of pregnant women found that milk consumption and season of the year have the largest effect on blood lead levels. For these women, a multivariate model showed the difference by stating, "the lowest expected value of BPb [blood lead] of 4.3 ug/dl was for a blood sample taken during summer in a woman who consumes milk products 3-4 times/week. The highest expected BPb level of 15.3 ug/dl was for a blood sample taken during winter in a woman who consumes milk products 0-2 times/week" (Farias 1996). **Thus, for the same lead exposure the blood lead level can be as much as 3.6 fold higher as a result of nutritional and seasonal factors.**

3) Children living in a "deprived" environment, as is more likely to occur in a family living in poverty, may be more likely to have more severe neurological defects as a result of lead exposure (Schneider et al. 2001).

Poverty in Manitoba is often associated with lower milk consumption. In northern Manitoba this is because of the high cost of milk in northern and remote communities. It is possible that a nutritional deficiency – low calcium from low milk consumption – could contribute to increased blood lead levels and be another reason why poverty may be associated with a higher blood lead level. The reason for the seasonal difference in the above study in Mexico is not clear, but could relate in part to variations in vitamin D status (higher in summer than winter), with vitamin D increasing calcium absorption. If this is a reason for the difference in lead levels it has particular relevance to Manitoba where the incidence of low or low-normal vitamin D levels is higher because of our climate.

The conclusion that lead and poverty are linked is inescapable. Lead exposure likely causes or contributes to poverty. Poverty increases the likelihood that children living in poverty will be exposed to lead and experience lead toxicity. Lead exposure is more likely to occur in neighbourhoods with low incomes, and children in low income families are more likely to have nutritional deficiencies which amplify the lead absorption. The results also emphasize the importance of addressing both lead exposure and nutritional status in any child with a high blood lead level.

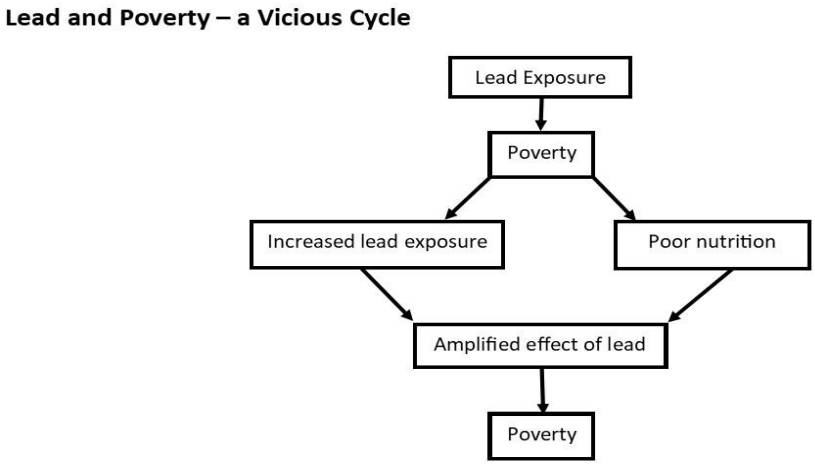


Figure 22: Poverty and lead are be closely linked

3) Does Poverty cause crime?

While there have been a variety of studies which link poverty and crime, violent and property crime rates from 1960 to 2012 in the United States do not correlate well with the level of poverty (Figure 18) (Faulk 2016). It is therefore unlikely that poverty alone is a direct cause of increased criminal activity.

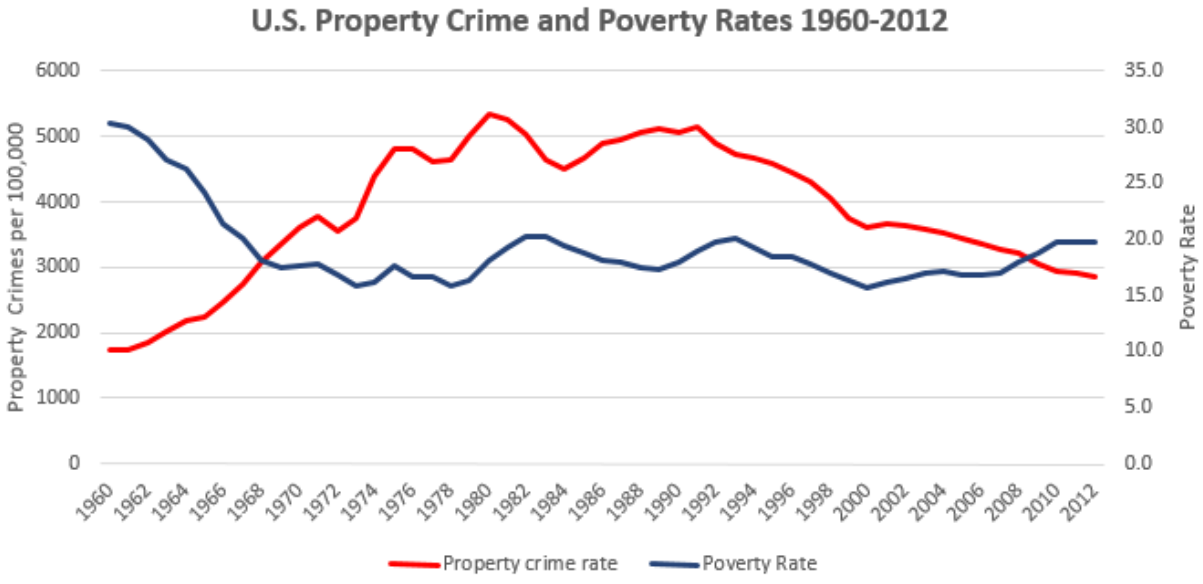


Figure 18: A graph (from Faulk 2016) showing that here is little overall correlation between the extent of poverty and the rate of property crime in the United States between 1960 and 2012, or between changes in the extent of poverty and changes in the rate of property crime.

Additional information which suggests that lead causes crime independent of poverty comes from a study by Feigenbaum and Muller (2016). These authors looked at the relationship, in the United States between a city's use of lead pipes to supply water and the homicide rate for the city. The water pipes were installed in the cities in this study between 1870 and 1896. The homicide rates were studied for 1921-1936 before leaded gasoline became a major confounding variable in lead exposure. They found that, "cities using lead pipes had homicide rates more than two and a half times the rates of cities that used iron pipes" (Figure 19). They used various approaches to isolate the effect of lead from other variables. This included separating any local effect of a lead refinery.

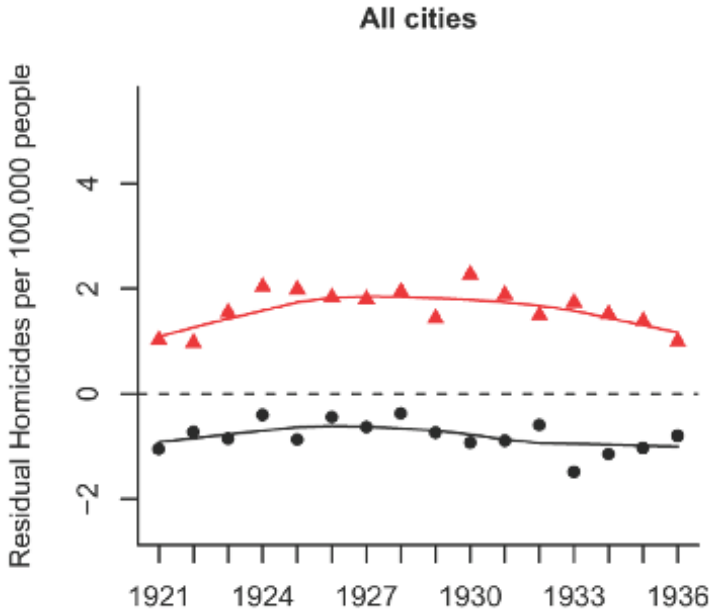


Figure 19: The difference in the homicide rates in cities with lead pipes (red triangles) and cities which used iron pipes (black circles). Cities with lead pipes showed consistent increased homicide rates from 1921 to 1936 (figure from Feigenbaum and Muller 2016).

To look more specifically at the impact of lead, they used knowledge that lead will leach from pipes into the water only when the water is acidic. They compared the association of lead pipes and the homicide rate for cities with acidic water (pH less than 7). They found the spread in homicide rates between cities with lead pipes and iron pipes was increased in cities with acidic water (Figure 20). In contrast, there was no difference between cities with lead and iron pipes for cities with basic water (pH above 7) (Figure 21). This result is consistent with the lead, leaching from the pipes only under acidic conditions, being the primary factor in the increased homicide rate. Further supporting this postulate, they found that, "as the water in a city becomes more acidic, moving down the original pH scale, homicide rates rise accordingly."

They then took their analysis one more step. Poverty was associated with an increase in infections due to tuberculosis and typhoid during the period studied. There was no difference in the rates of tuberculosis and typhoid infections between cities with lead pipes compared to those with iron pipes. This provides evidence that poverty differences between cities with lead and iron pipes were not

responsible for the increased crime in cities with lead pipes and acidic water. There was, however, an increase in cirrhosis of the liver in cities with lead water pipes compared to cities with iron pipes. They did find an increase in cirrhosis in cities with lead pipes. The increase in cirrhosis is consistent with the postulate, discussed earlier, that lead exposure increases alcohol consumption and alcohol abuse. The results of Feigenbaum and Muller's analysis is thus consistent with a specific effect of lead to increase crime.

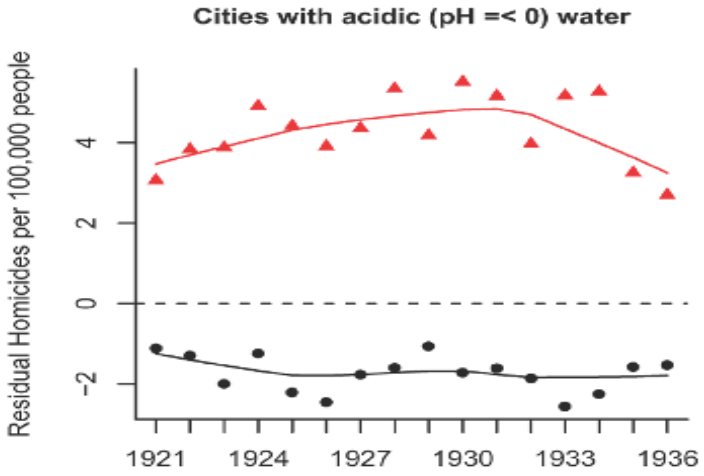


Figure 20: When only cities with acidic water (pH less than 7) were evaluated, then there was a larger difference between cities with lead pipes (red triangles) and cities with iron pipes (black circles)(data from Feigenbaum and Muller 2016). These differences were consistent across all years from 1921 to 1935. Note that acidic water in iron pipes has a slightly reduced level of homicides. It is possible that this is due to iron leached from the pipes due to the acidic conditions blocking the absorption and the negative effect of lead exposure from other sources.

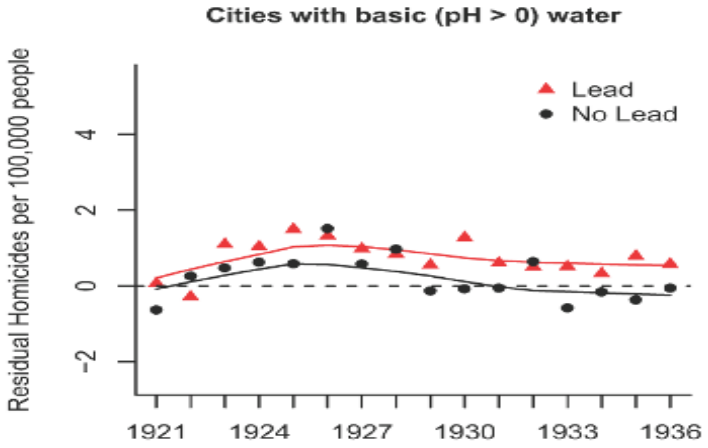


Figure 21: When only cities with basic water (pH above 7) were analyzed there was no significant difference between cities with lead pipes (red triangles) and cities with iron pipes (black circles) (data from Feigenbaum and Muller 2016). This is presumed to be due to the fact that lead in lead pipes does not leach from the pipes into the water under basic conditions. The results were consistent from 1921 to 1936.

In summary increased blood lead and body lead burden may be a primary reason why individuals living in poverty are more likely to be associated with criminal activity. It is possible that under conditions of low lead exposure, people living in poverty may not be more likely to commit crimes, whereas under conditions of poverty where there is lead exposure, increased criminal activity is likely.

The Pathway(s) from Lead Exposure to Criminal Activity including Violent Crime:

The link between lead and crime is complex because of the impact of the changes produced by lead on brain function. The evidence suggests that lead's impact is in part to increase susceptibility to substance abuse and to mental illness. This means that it has been easy to ascribe the problems with crime to substance abuse without considering adequately the underlying cause(s) of the substance abuse. The fact that poverty is associated with conditions which increase lead exposure and increase lead absorption into the body means that it has been easy to suggest that crime is due to poverty. When the whole picture is considered, including the indirect role of lead to increase substance abuse and the impact of poverty on lead toxicity, it becomes easier to see why and how lead may be a central underlying cause of crime. Initially, I was very skeptical of the evidence that lead could account for 50 to 90% of the variation in crime. My skepticism was heightened when I talked to a pediatrician who said, "The problem is not lead, it is substance abuse." However, when seen in the context of the pathways through which lead exposure occurs and the impacts of lead directly and indirectly on human behaviour, the relationship between lead and crime, in this context, is probable and makes sense (Figure 23).

Fully understanding the interaction of lead with other factors which have been associated with increased crime, including violent crime, is important. Factors including as an example being in foster care as a child (Ellis et al 2019, Denno 1990, Brownell 2020) are explored later.

A study of Fergusson et al (2008) is of interest in understanding the pathway(s) by which lead may act to cause an increase in crime. This study in New Zealand showed a striking relationship between dentine (tooth) lead levels and crime as shown in Figures 24 and 25. The analyses in the publication were consistent with a considerable proportion of the impact of lead on crime being due to the effect of lead on educational achievement consistent with the known impact of lead on learning and behaviour. Fergusson's study thus provided critical evidence that educational underachievement as a result of lead exposure was likely an intervening variable. He found in his words the likelihood of "a causal chain process in which lead exposure lead to impaired educational performance, which, in turn, is reflected in increased risks of crime."

Pathways for lead exposure to lead to crime

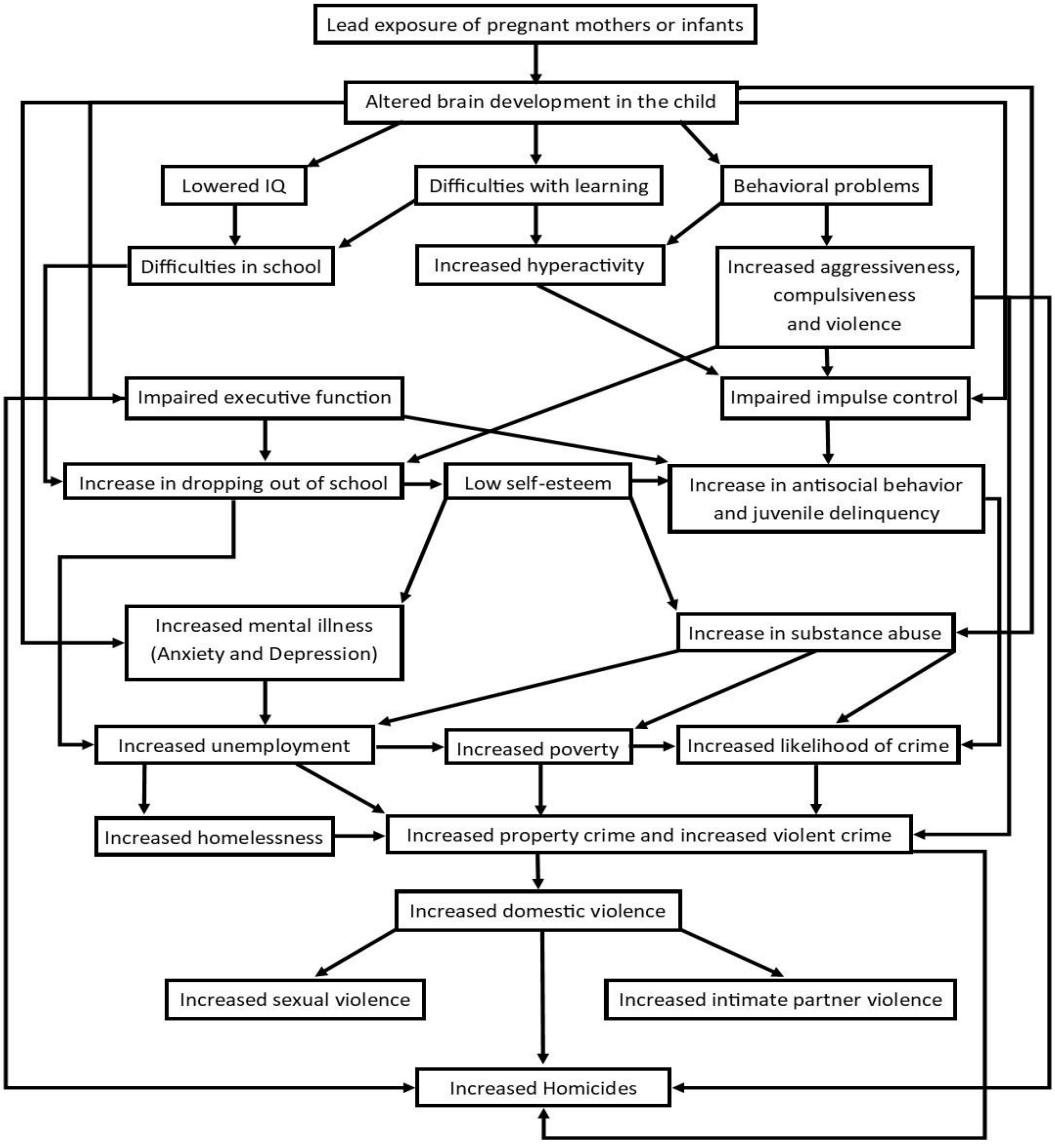


Figure 23: The impact of lead on crime passes through many pathways as shown in the Figure.

Figure 26 provides a simplified view of the proportion of the self-reported offences which could be due to lead. If the blood lead level of 0 to 2 ug/g is taken as the basal level, then the proportion of self-reported property and violent offences above this level may be caused or facilitated by lead. The calculated proportion in this instance is that lead may have an impact to contribute to 74 percent of self-reported criminal offences from this cohort in the Christchurch urban area at the time of the study. It is worth comparing Figures 26, 31 and 35. Figure 35 (Appendix 2) shows the impact of intervening where the lead level is high. With the demonstration in Figure 35, that it is possible to reduce the lead associated violent crime rate to a "basal" level which is found at 2 ug/dL in blood, it adds credence to the concept that much of this crime is lead related and not the result of an impact of a confounding variable or variables. For more on this study see Appendix 1.

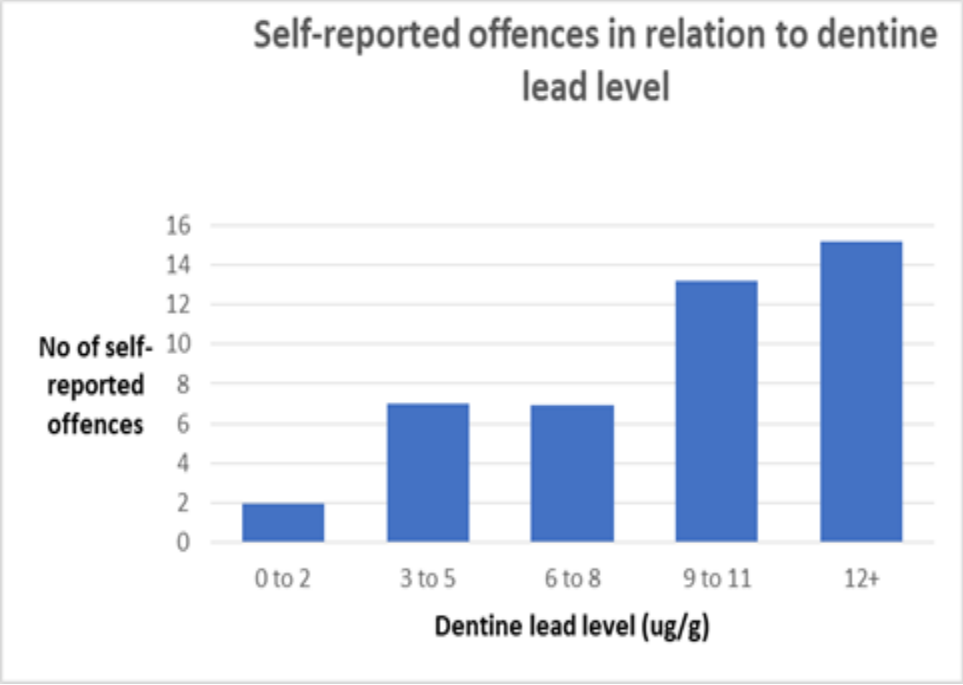


Figure 24: Results of a study of a cohort of 1265 children (635 boys and 630 girls) born in the Christchurch urban area of New Zealand in 1977. Lead levels were measured in deciduous teeth shed when the children were aged 6-8 years of age. Self-reported offences from age 14 to 21 were evaluated through interviews conducted with the youth when they were ages 15, 16, 18 and 21 years of age. At ages 15 and 16, the Self-Report Early Delinquency Scale was used, and at ages 18 and 21 offending was assessed using an instrument based on the Self-Report Delinquency Inventory. Property and violent offences were included. Theft, burglary, breaking and entering, vandalism, fire setting, were included as property offences and assault, fighting, use of a weapon or threats of violence against a person were included as violent offences (Data are from Fergusson et al 2008).

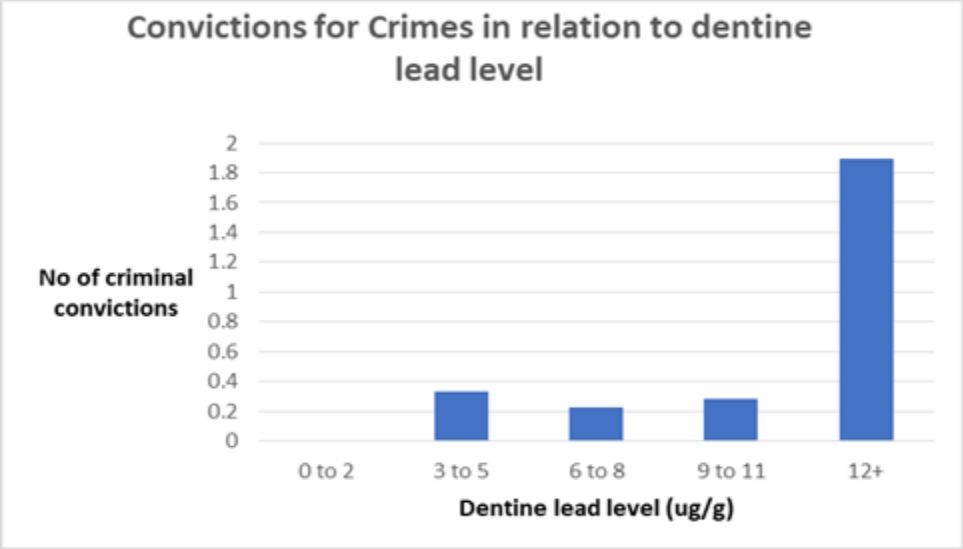


Figure 25: This information is from the same study as Figure 24 (Fergusson et al 2008). The number of criminal convictions were from data obtained from the New Zealand police and covered the period when the subjects were age 14 to 21. Property and violent offences were included. The number of convictions for property and violent offences were added up for each subject. The averages are recorded in the graph. The number of subjects with lead levels of 0-2 ug/g was 88; at 3-5 ug/g was 416; at 6-8 ug/g was 239; at 9-11 ug/g was 84; and at 12 or more ug/g was 44.

Basal level of self reported offences and the additional offences related to lead

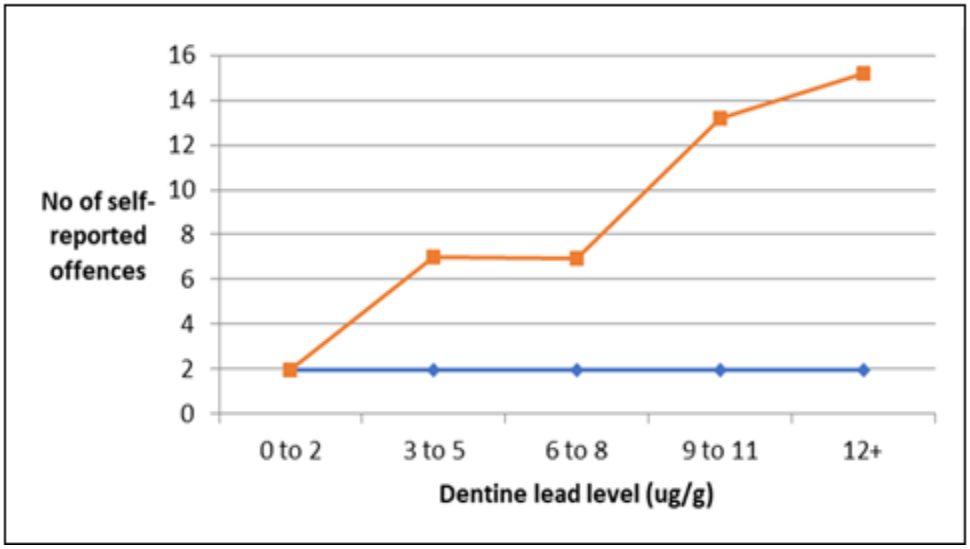


Figure 26: Graph showing the basal level of self-reported offences under conditions where dentine lead level is low (blue diamonds), and the increase associated with higher dentine lead levels (orange squares). The increase in self-reported offences associated with levels of lead of 3 ug/g and above represents 74% of all offences (Data are from Fergusson et al 2008).

The impact of lead exposure is intergenerational

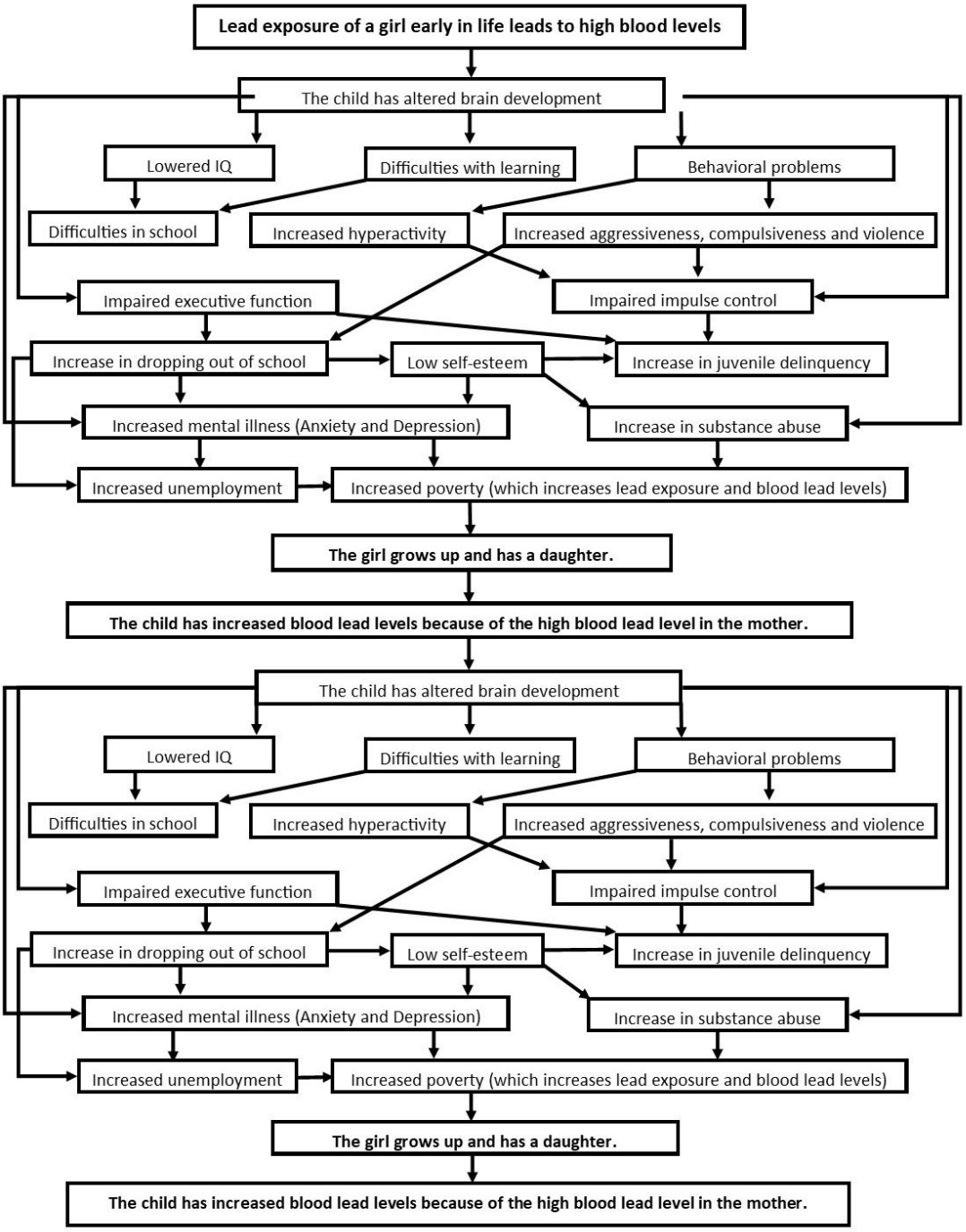


Figure 27: The impact of lead is intergenerational, and it can continue from mother to daughter to granddaughter and on if not checked as shown in the figure.

There has been much discussion of the fact that issues of violent crime including sexual abuse are intergenerational. There has been discussion of the fact that poverty can be intergenerational, though there are clearly many who are exceptions. It is in this context that it is important to emphasize that the

impact of lead is intergenerational. A mother who is exposed to lead and has high blood lead levels when she is pregnant will have sons and daughters who are affected by the lead which causes neurodevelopmental problems leading to learning and behavioural problems. The daughter, unless the lead exposure is addressed, may pass the lead on to her sons and daughters. There are, as shown, varied pathways through which lead can exert its intergenerational impact. Addressing lead exposure and lead levels in the body becomes even more important when one considers that this can interrupt a vicious intergenerational cycle.

Children with high blood levels can be helped and can do well:

There is urgency in acting to intervene where children have high blood lead levels because they can be helped. Billings and Schnepel (2015) studied the impact of early interventions on children found to have lead levels over 10 ug/dL. They studied 3472 children born between 1990 and 1997 and who attended school in Charlotte-Mecklenberg County, North Carolina, the 18th largest school district in the United States. All received an initial blood lead test around one to two years of age (mean age 28 months) as part of a lead surveillance program. Of these children 1952 had an initial blood lead level less than 5 ug/dL; 1072 children had a blood lead level between 5 and 10 ug/dL; and 301 children had a blood lead level > 10 ug/dL. When the children with blood lead levels above 10 ug/dL were retested, 119 had a blood lead level $\geq$ 10ug/dL and 182 had a blood lead level $\geq$ 5 ug/dL but < 10 ug/dL. They studied, in depth, the 119 children with two blood lead levels $\geq$ 10 ug/dL who received an intervention (the intervention group) and the 182 children with a first blood lead level of $\geq$ 10 ug/dL but a second blood level which was <10 ug/dL but $\geq$ 5 ug/dL (the control group which did not receive any intervention). They also looked at all children for delinquent and criminal activity. In the primary comparison, the control group of children had an initial blood lead level above 10 ug/dL similar to the intervention group, but their second blood lead level was lower between 5 and 10 ug/dL. The intervention group were eligible for an intervention which included lead remediation, nutritional assessment, medical evaluation, developmental surveillance and a public assistance referral. The control group was not eligible for the intervention and did not receive it.

The two groups of children were comparable on a variety of demographic and observational parameters. The fact that the mean blood level of the initial blood test was higher in the intervention group (17.9 ug/dL) than in the control group (12.1 ug/dL) would, if anything, tend to bias the study against finding an effect of the intervention. It is also to be noted that the second blood lead levels in the control group (between 5 and 10 ug/dL) were in the range at which it is now accepted that there are significant adverse impacts of lead exposure. Consistent with this, the United States CDC has since lowered their “alert” level from 10 ug/dL to 5 ug/dL. The study of Billings and Schnepel found that the negative outcomes associated with early life exposure were largely reversed by the interventions with large and significant declines for children in the intervention group in anti-social behaviour; school suspensions; school absenteeism; school crime; arrests for property crime; arrests for violent crime; and all arrests (Figures 28-32).

As the authors of the study say, “Our results suggest that the effects of high levels of exposure on antisocial behaviour can largely be reversed by the intervention – children who test twice over the alert threshold [those who were to receive the intervention] exhibit similar outcomes as children with lower levels of exposure BLL < 5 ug/dL).”

Figures 28-32 (data taken from the original paper) show the details of the number of school absences; the number of school suspensions, the number of property crimes; and the number of violent crimes in relation to the initial blood lead levels of the children studied. In each case there is an increase as the blood lead level increases. In each case, the intervention group shows a substantial reduction of the

impact of lead on the children. In the case of violent crime, the level of violent crime in the intervention group was reduced by 94% to the level seen in children with only 2 ug/dL blood lead level.

The work of Billings and Schnepel applies to children with levels of 10 ug/dL or higher. They show that early interventions make a big difference to prevent the lead from having adverse effects on the child later on. We now know, however, that we need to be dealing with levels of 5 ug/dL (0.24 umol/L) and above. Beller describes a meeting in 2015 shortly after this lower level was recognized as the level needing action. "In 2015, I attended the Healthy Housing Conference in a hotel ballroom in New Orleans. The CDC had recently updated their guidelines regarding acceptable levels of lead in a child's blood, lowering the threshold from 10 to 5 ug/dL. In theory, every child with a level about 5 should now be visited by a social worker who should assist the family and the landlord in identifying the lead source and remediating it. **We are not, in Manitoba, at the state of action that is described here. We need to be. Each child with a level of 5 ug/dL (0.24 umol/L) and above needs to receive individual lead remediation as well as medical, nutritional and public health attention.**

It is important to emphasize that every child with a blood lead level of 5 ug/dL or above needs to be investigated as to the source of the lead, and to have changes made to decrease ongoing lead exposure. The half-life of lead in blood is 30 days. Notwithstanding this, the reduction in blood lead may be much slower than this half-life because of the lead already accumulated and stored in bones and teeth. It is important to reduce continuing exposure. This is an essential part of the successful approach to reduce the impact of lead on children who have already been exposed. The other essential part to enable children exposed to lead to do well is to help the child with optimum nutrition and optimum support with learning and other functional shortfalls and with public health attention to address family needs.

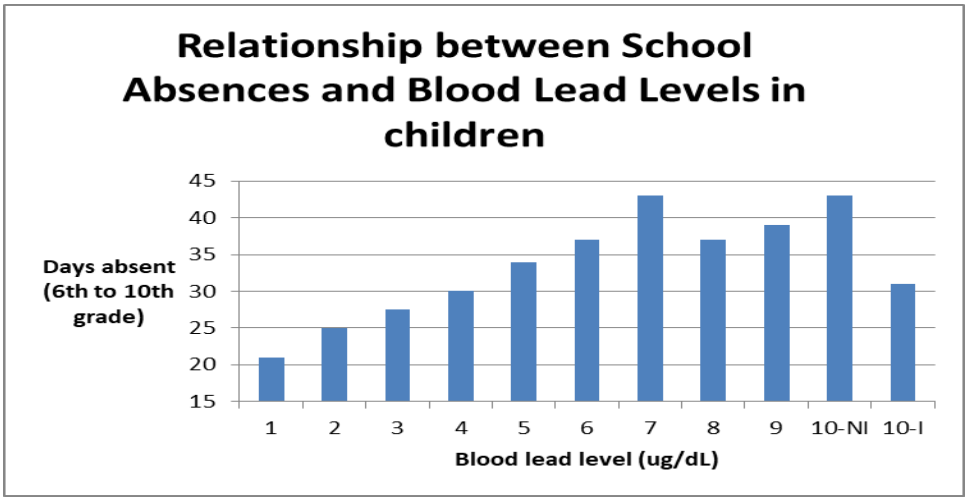


Figure 28: Children with higher blood lead levels had more days absent from school with a gradient showing the effect of blood lead levels starting as low as 2 ug/dL. Early intervention to reduce lead exposure reversed the impact of the lead and reduced the number of school absences. (NI = no intervention; I = intervention; groups 1-9 also had no intervention) (Figure is redrawn from Billings and Schnepel 2018).

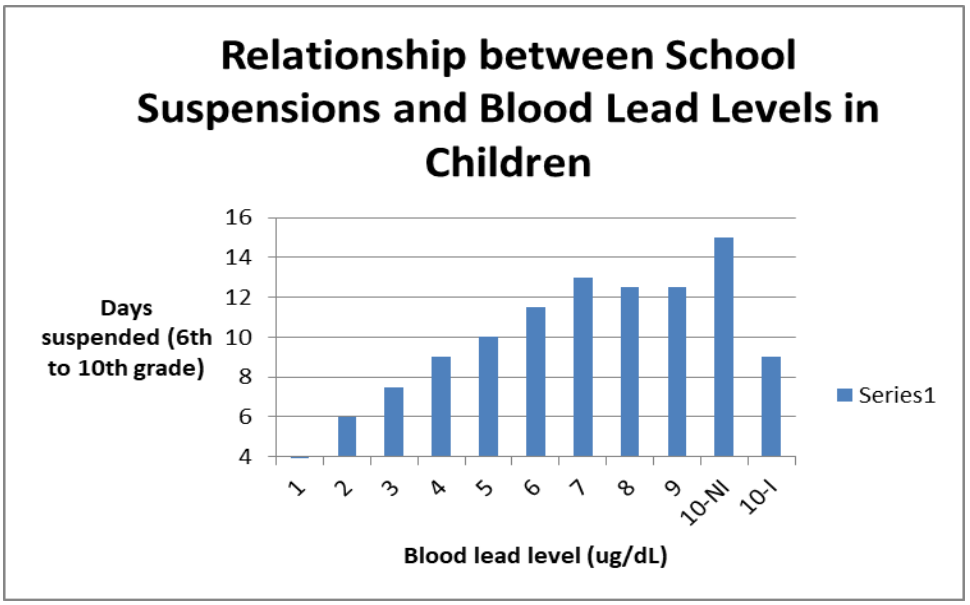


Figure 29: Children with higher blood lead levels showed an increase in school suspensions with a gradient showing the effect of blood lead levels starting as low as 2 ug/dL. Early intervention to reduce lead exposure and to reverse the impact of the lead reduced the number of school suspensions (NI = no intervention; I = intervention; groups 1-9 also had no intervention) (Figure is redrawn from Billings and Schnepel 2015).

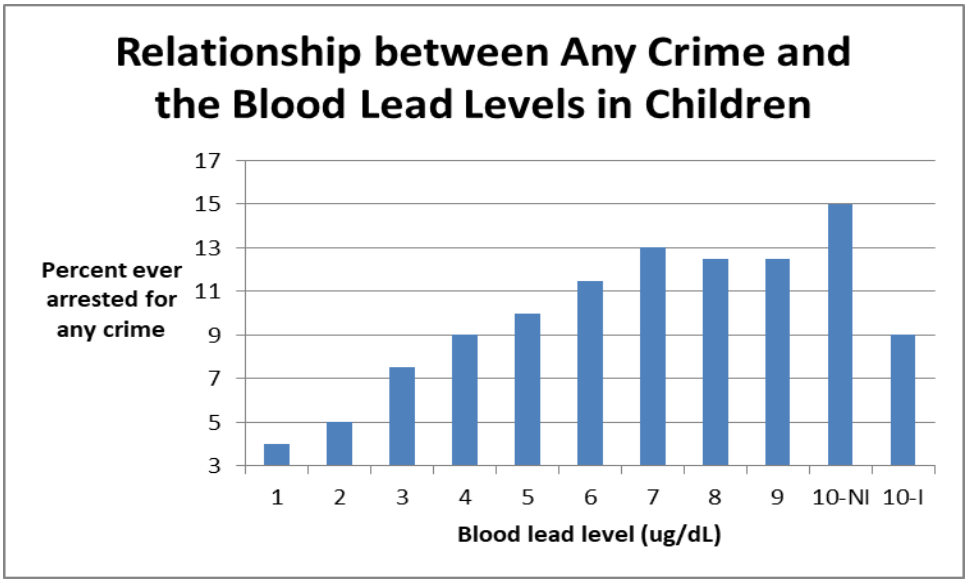


Figure 30: Children with higher blood lead levels showed an increase in any crime with a gradient showing the effect of blood lead levels starting as low as 2 ug/dL. Early intervention to reduce lead exposure and to reverse the impact of the lead reduced the proportion of children who were arrested for criminal activity as a youth or adult (NI = no intervention; I = intervention; groups 1-9 also had no intervention) (Figure is redrawn from Billings and Schnepel 2018).

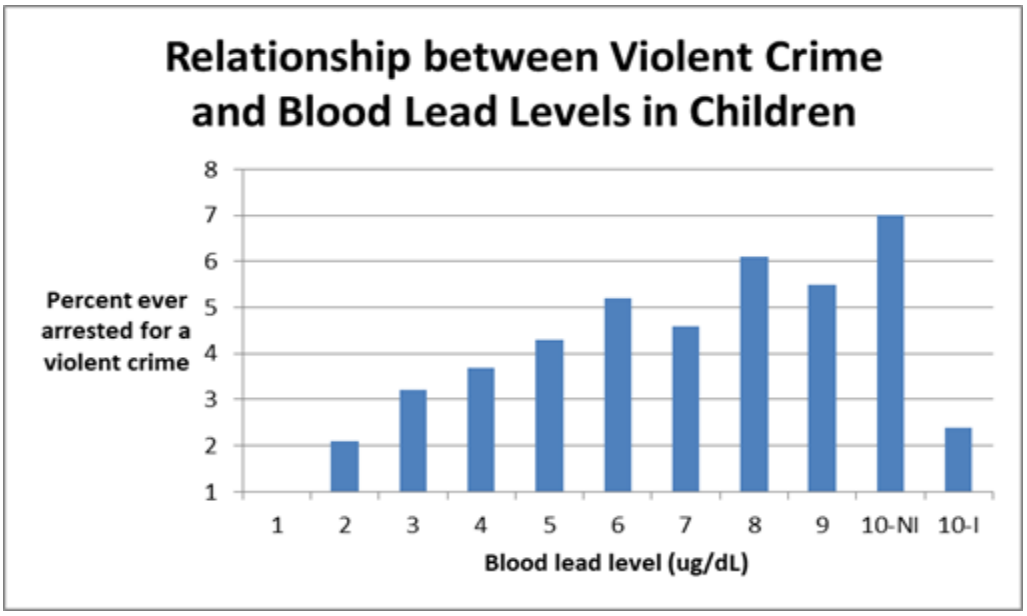


Figure 31: Children with higher blood lead levels showed an increase in violent crime with a gradient showing the effect of blood lead levels starting as low as 2 ug/dL. Early intervention to reduce lead exposure and to reverse the impact of the lead reduced the proportion of children who were arrested for a violent crime as a youth or adult (NI = no intervention; I = intervention; groups 1-9 also had no intervention) (Figure is redrawn from Billings and Schnepel 2018).

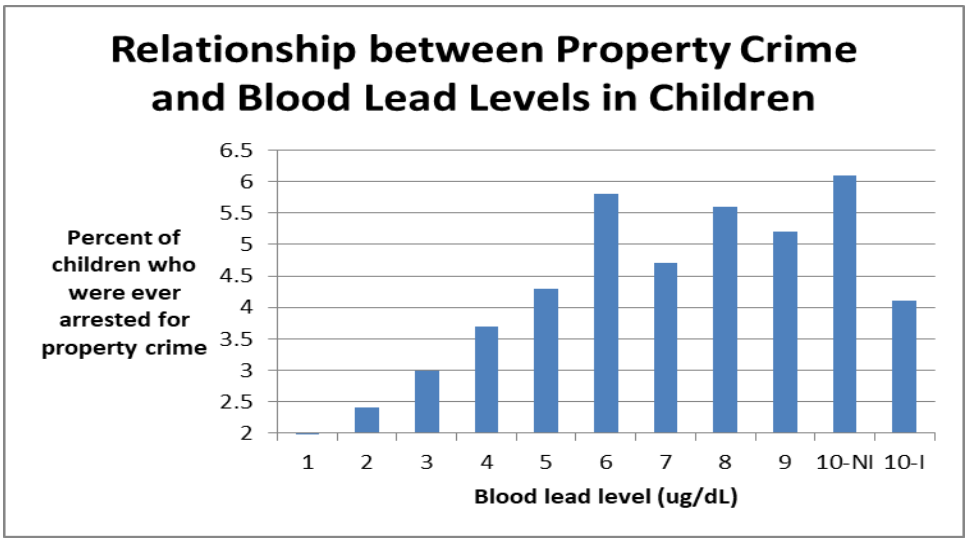


Figure 32: Children with higher blood lead levels showed an increase in property crime with a gradient showing the effect of blood lead levels starting as low as 2 ug/dL. Early intervention to reduce lead exposure and to reverse the impact of the lead reduced the proportion of children who committed a property crime as a youth or adult (NI = no intervention; I = intervention; groups 1-9 also had no intervention) (Figure is redrawn from Billings and Schnepel 2018).

Addressing Lead Toxicity is also addressing Racial Inequalities:

Discrimination based on race continues to be a significant issue in Manitoba and this needs to be considered. It has been highlighted by Indigenous people, in the Black Lives Matter movement and by other ethnic groups. Of interest, results of vigorously addressing high lead levels in children are now having a broad and positive impact to reduce racial inequalities in Chicago as demonstrated in a study of Sampson and Winter (2016). This research looks at "lead toxicity as a major environmental pathway through which racial segregation has contributed to the legacy of Black disadvantage in the United States." They demonstrate that "lead toxicity is a source of ecological inequity by race and a pathway through which racial inequality literally gets into the body." The authors also show that for the period from 1995 to 2010 there have been "dramatic declines in lead toxicity across Chicago, especially in neighborhoods that began the period with very high prevalence rates. These declines reflect the success of public lead reduction efforts, including rigorous testing, lead-based paint abatement of homes and other locations where children spend considerable time, and improvements in nutritional status among children. A universal program, these efforts disproportionately benefited minority neighborhoods where lead levels had been particularly toxic. In this sense, population health interventions may be seen as an important source of reducing racial inequalities. To be sure, Black-White disparities remain, but the absolute improvement in the lives of Black children is a source of good news. The medical community is to be commended for bringing the lead epidemic to the attention of the public and prodding us to include lead toxicity in our theoretical framework and policy."

This brings us to – **what do we need to do?** For the fact that action now can make a big difference means there is urgency to act now. But we first need to consider the cost-benefit analysis for making investments to reduce blood lead levels and to address possible alternative hypotheses for the causes of crime in Manitoba.

Cost-Benefit Analyses with respect to addressing the effect of lead on human health.

The recent UNICEF-Pure Earth report says with regard to investments to reduce lead exposure that, "The return on investment is enormous: improved health, increased productivity, higher IQs, less violence and brighter futures for millions of children across the planet." And this does not include the savings from decreased crime. To this list can also be added improved educational outcomes, improved future prospects for employment and higher wages, as well as improved social potential for children, decreased crime and decreased racial inequalities.

The Pew Charitable Trusts (2017) in a careful study of cost/benefits for addressing the impact of lead on human health in the United States makes the following points:

1) "Ensuring that contractors comply with the Environmental Protection Agency's rule that requires lead-safe renovation, repair, and painting practices would protect about 211,000 children born in 2018 and provide future benefits of $4.5 billion, or about $3.10 per dollar spent. This includes $990 million in federal and $500 million in state and local health and education savings and increased revenue. The effort would cost about $1.4 billion"
2) "Removing leaded drinking water service lines from the homes of children born in 2018 would protect more than 350,000 children and yield $2.7 billion in future benefits, or about $1.33 per dollar invested. Of those benefits, about $2.2 billion in higher lifetime earnings, better health, and other gains would accrue to 272,000 children born in the 2018 cohort, and $550 million would come from protecting the roughly 80,000 other children born into those homes over the next 10 years. The total includes $480 million for the federal government and $250 million for states and municipalities from health and education savings and increased tax revenue associated with higher earnings among the cohort. Replacing these lead pipes would cost an estimated $2 billion."
3) "Eradicating lead paint hazards from older homes of children from low-income families would provide $3.5 billion in future benefits, or approximately $1.39 per dollar invested, and protect more than 311,000 children. About $2.8 billion of those benefits would accrue to roughly 244,000 of the 4 million children in the 2018 cohort. The other $670 million in benefits would accrue from protecting approximately 67,000 additional children born into those homes over the next 10 years. The total benefits include $630 million in federal and $320 million in state and local health and education savings and increased revenue. Controlling lead paint hazards would cost $2.5 billion for the 2018 cohort."

Gould (2009) also looked at the costs and benefits of reducing lead exposure to children in the United States. She found that "the costs of lead hazard control range from $1.2 to $11.0 billion. The benefits to lead hazard control is the sum of the costs for medical treatment ($11–$53 billion), lost earnings ($165–$233 billion), tax revenue ($25–$35 billion), special education ($30–$146 million), lead-linked ADHD cases ($267 million), and criminal activity ($1.7 billion), for a total of $192–$270 billion. The net benefit

of lead hazard control ranges from $181 to $269 billion, resulting in a return of $17–$221 for each dollar invested in lead hazard control."

Grosse et al (2002) looked at the economic benefits from improved worker productivity as a result of reducing lead exposure. They estimated the economic benefit from improved productivity would be between $110 billion and $319 billion for each cohort of 3.8 million 2-year old children in the U.S.

When considered in terms of the total impact of lead on adult health as well as on the health of children and youth, and at a global scale the impact of addressing lead exposure is enormous (Rees and Fuller 2020).

In summary, there is substantial evidence for major economic benefits from reducing blood lead levels and the myriad of effects of lead exposure.

Addressing Alternatives to lead as causes of crime:

Many alternative hypotheses have been put forward as to the causes of crime. This report will not deal with all of them, but will address certain particular aspects that have been suggested in Manitoba. Poverty has already been discussed earlier and this will not be repeated. As well, additional criticisms of the concept that lead exposure leads to crime are to be found in Appendix 15.

Children who are taken into foster care through child and family services agencies:

Blood lead levels:

Children who are found to have a failure to thrive or who suffer physical abuse have disproportionately high lead levels. Consistent with this is a study of 519 children in Philadelphia tested before they were taken into foster care. The results showed that, "1 of every 2 children screened before placement had blood lead levels ≥20 μg/dL at the peak prevalence (at ages 19–24 months), and nearly 9 of 10 children had levels ≥10 μg/dL" (Chung et al 2001). This represents a very high proportion of children taken into care with high blood lead levels. The authors point out that, "these findings are alarming and disproportionate to the general population." The authors also found that blood lead levels of biological siblings of children in foster care were also very high and that these children, "are at very high risk for lead poisoning." While this study is evidence that many children in Philadelphia taken into foster care had high lead levels, it is not necessarily applicable to Manitoba because of the difference in our populations.

Children in the care of Family Services and Criminal Activity:

Marni Brownell et al (2020) has documented the increased likelihood of a child in the care of Child and Family Services (CFS) in Manitoba being involved with the youth justice system and being charged with an offence. Manitoba has a higher rate of children in care than all other provinces in Canada. Manitoba also has the highest youth incarceration rate of all provinces. It is logical to consider whether a child who had been in care would be more likely to be arrested for a crime in Manitoba. To evaluate this connection, Brownell et al (2020) looked at all Manitobans (18,754) who were born in the calendar year 1994, and looked at their involvement with the child welfare system and their involvement with Manitoba's youth criminal justice system. What they found was that, "by the time they were young adults (age 21), close to half of individuals [48.3%] who spent time in care as children had been charged with a criminal offence … 54.6% of males and 42.2% of females." The proportion is very high considering that for the 1994 cohort, children who were ever in care made up only 7.9% of the total cohort of children. In a further comparison, only 7.0% of children who were never involved with CFS had been charged with a criminal offence. The statistics are stark in showing that children who are ever in the care of CFS are much more likely to be involved with the justice system and to be accused of a crime.

The question of why children in care are more likely to be accused of a crime was explored through a look at the characteristics of the children in care. Brownell et al (2020) found "the [high school]

graduation rate for youth who had ever been in care (regardless of whether they were accused or not) is 38.0%". This contrasts with a high school graduation rate for children who had never been involved with CFS of about 90%. Second, about 64% of children who had ever been in care were diagnosed with ADHD, conduct disorder, mood disorder, anxiety disorder, psychotic disorder or a substance use disorder, while only 28% of children who had never had any involvement with CFS had one of these diagnoses. Third, about 13.5% of children who were ever in care were diagnosed with an intellectual disability compared to only about 2% of children who were never involved with CFS. Fourth, as an indicator of poverty, 26.3% of children who had been in care had ever received income assistance between ages 18 and 21, while only about 2.7% of children who were never associated with CFS, received income assistance.

All four of the above indicators (lack of high school graduation, brain health conditions, intellectual disability and poverty) have been associated with an increased likelihood of criminal activity and could be contributing factors towards criminal activity. Interestingly, all four of these factors have also been associated with high blood lead levels and it is possible that lead could contribute to the increased likelihood of individuals being accused of criminal activity by producing alterations in brain function leading to these outcomes. Clearly, if lead has a major role in increasing crime in Manitoba, then it is likely that it would have a role in all children including those who have ever been in care (as shown in the accompanying figures). This role might be an effect of the lead on the child (Figure 33) or an effect of the lead on the parents (Figure 34). The author was unable to locate any research to address this and lead toxicity is never mentioned in the study of Brownell et al (2020). This is therefore an area which will require investigation to determine whether there is a link, or multiple links, between lead toxicity of the child, the parent or both, as well as the likelihood of a child being in care and the likelihood children who have been in care will be involved with the criminal justice system.

Brownell et al (2020) also address the fact that indigenous children are overrepresented in CFS care and in the criminal justice system. They say, "The high rates of children in care and youth criminal justice involvement in Manitoba and the over-representation of Indigenous children and youth in both systems reflect a multitude of structural determinants – including historical, political, societal and economic factors that continue to create challenges for Indigenous families. Key among these is the harm caused by centuries of colonial policies, laws and practices based on domination and assimilation, including the residential school system, which systematically separated indigenous children from their families and communities, cutting them off from their caregivers, their language and their culture." They add, "These social and societal forces – colonialism, racism and structural violence – cannot be directly measured using the data available in this report, but we disaggregated many of the results by "Indigenous identity" as a proxy for these forces in an attempt to call attention to the impact of social and societal forces on child welfare and youth criminal justice systems involvement." They further add, "There are myriad reasons for the over-representation of Indigenous children in the child welfare and youth criminal justice systems, including historical and ongoing cultural policies (e.g. the residential school system; the Sixties Scoop; and current child welfare policies) that systematically separate Indigenous children from their families, communities, language and cultures; systemic racism with both the child welfare and youth criminal justice systems; chronic underfunding of prevention and support

services to Indigenous communities; and structural violence (systemic policies and structures that operate to deny basic human rights to specific populations and/or prevent specific populations from obtaining the resources necessary to achieve their full potential). Thus, Indigenous identity itself is not a risk factor for involvement in either or both systems rather it is the many social and societal forces that Indigenous peoples in Manitoba must contend with that put their children at greater risk of child welfare system and youth criminal justice involvement." It would be sad and ironic if one of the colonial legacies contributing to the number of Indigenous children in care and in the criminal justice system is lead.

It is important to add here that even if lead levels were to be found to be high in some Indigenous children, this does not take away from the importance of the above factors. Indeed, it is possible that the historical and current political, societal and economic factors circumstances could have contributed to increasing the lead burden in some children and to accentuating the effects of lead in some children.

Child and Family Services (CFS), lead and criminal activity -1:Lead exposure in the child

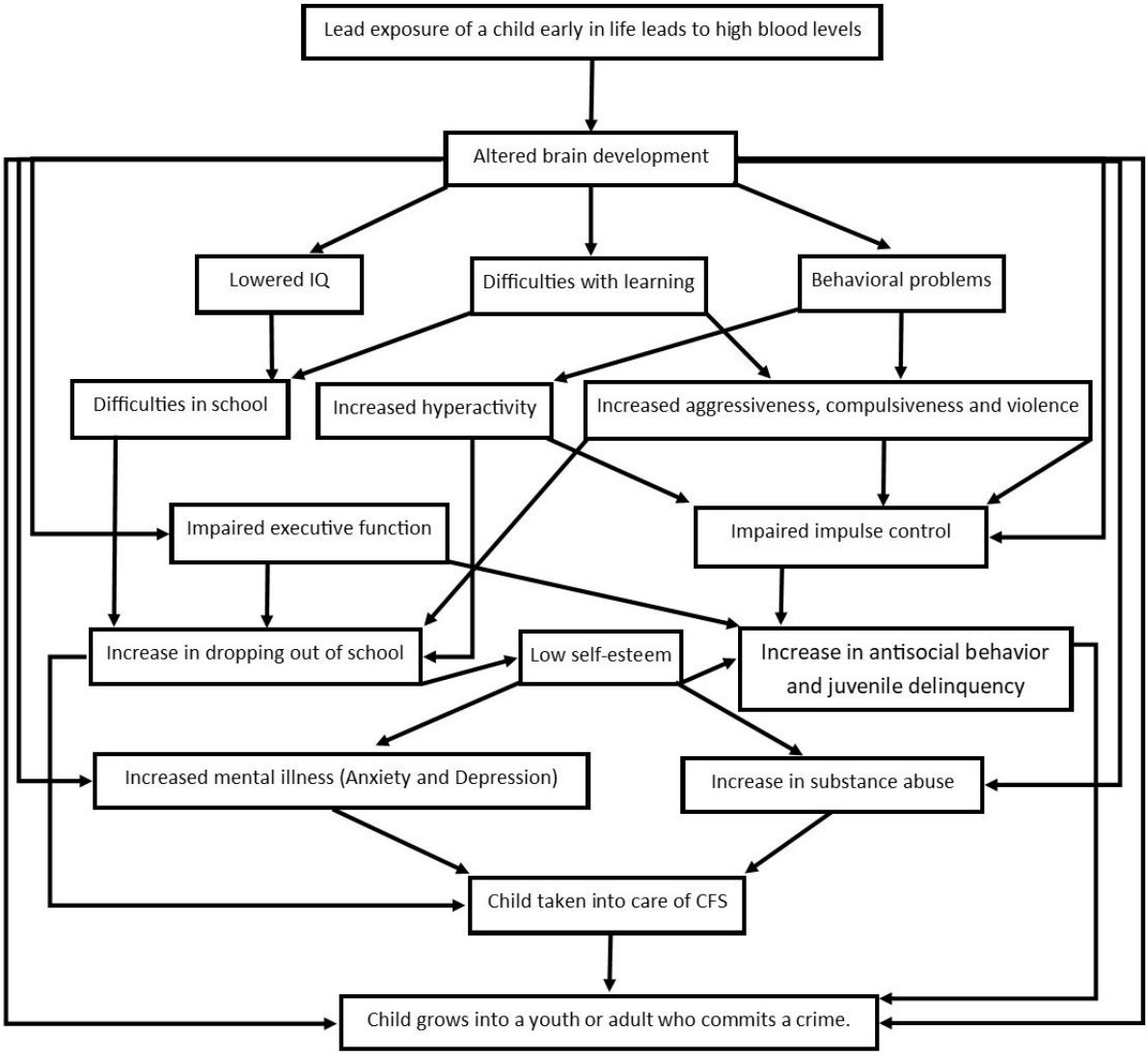


Figure 33: A child with high blood lead levels can be disruptive in a household and in a family that is having challenges for other reasons. This child may be more likely to be taken into the care of child and family services. The high lead level and the changes it causes to brain function coupled with the related difficulties of being taken into care can result in an increased likelihood of antisocial behaviour and criminal activity.

Child and Family Services (CFS), lead and criminal activity – 2: Lead exposure of a parent

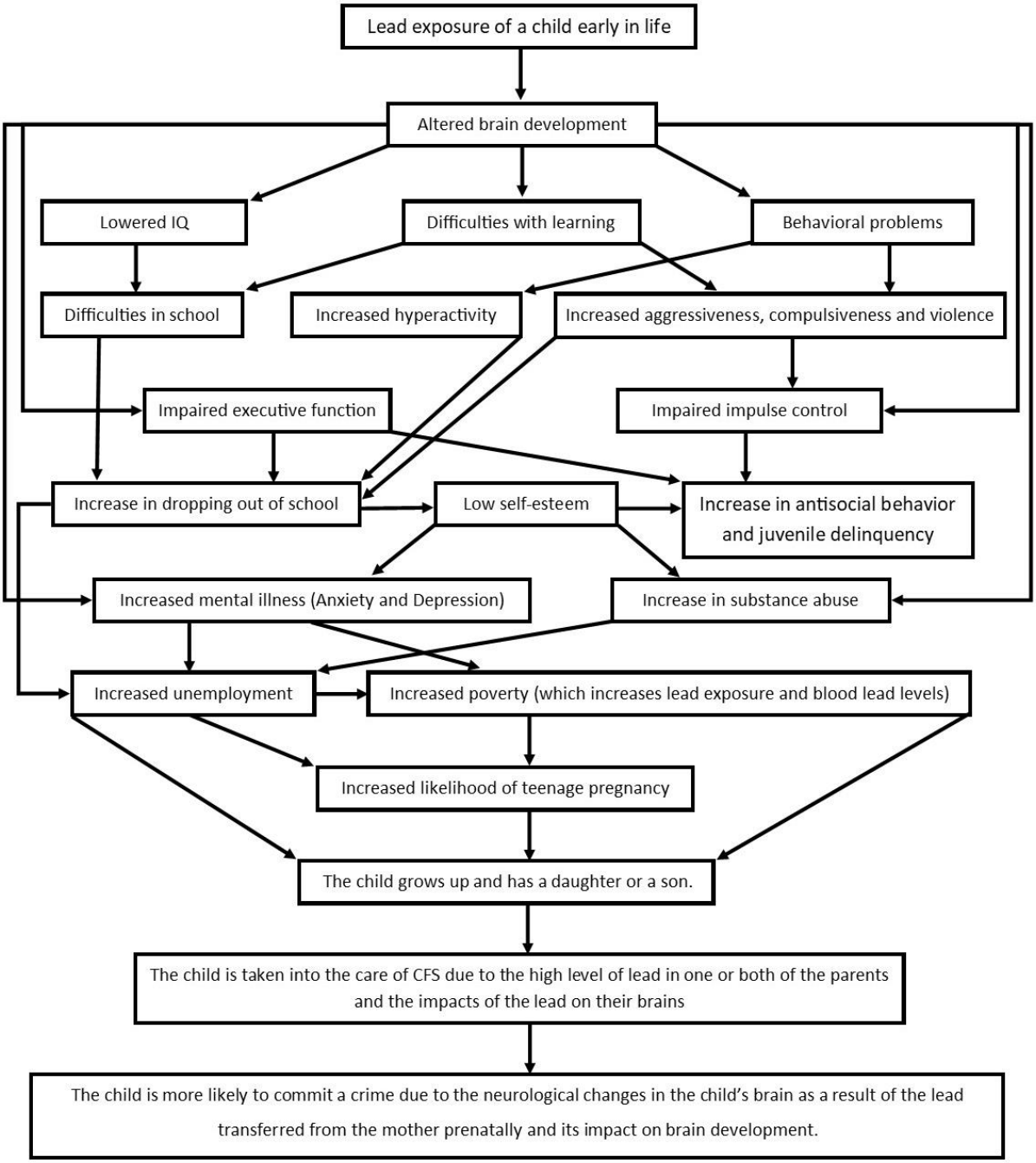


Figure 34: A mother or father with a high blood lead levels may be more aggressive and antisocial leading to family difficulties and the child being taken into care. The child of a mother with a high level of lead may be more likely to engage in antisocial activity including juvenile delinquency and criminal activity due to the child's lead exposure coupled to a destabilizing environment that the child has been in.

Fetal Alcohol Spectrum Disorder (FASD), Dyslexia and other learning disorders:

FASD has been associated with the potential for criminal activity. "Individuals with FASD have been shown to have a higher rate of incarceration and arrest, with approximately half of all people with FASD facing legal trouble at some point," (National Organization on Fetal Alcohol Syndrome 2020). The proportion of youth in the criminal justice system who have FASD has been found to be 23% in British Columbia (Fast et al 1999) and up to 40% in Saskatchewan (The Canadian Press 2000).

In addition, it must be considered whether other learning disorders besides those caused by lead and FASD could be precursors to criminal activity. A study of 253 prisoners randomly selected from 130,000 Texas prisoners showed two-thirds scored poorly in reading comprehension and that 48% were dyslexic with poor word decoding on the Woodcock Reading Mastery Test (Moody KC et al. 2000). A broader sample of incarcerated adults from 1415 prisoners in 80 prisons in the United States showed that 29% lacked basic literacy skills and struggled to pick out basic information while reading simple texts. As well, 52% lacked basic numeracy skills and had difficulty interpreting simple data or statistics in texts, tables and graphs (Rampey et al 2016). More recently, an evaluation in two prisons found evidence that half of inmates were dyslexic (Cassidy and Cassidy 2018). In 2018, the United States passed legislation to screen individuals who are incarcerated for dyslexia and to provide them help in getting their GED as a step to decreasing recidivism. The extent to which lead exposure or FASD may contribute to dyslexia is unknown. It is possible that other causes of dyslexia may contribute to crime and also need to be addressed.

However, before linking all learning disabilities together, a careful analysis by Brier (1989) of the relationship between learning disability and delinquency shows that while a learning disability is associated with an increased risk of committing a delinquent offence, the large majority (90%) of individuals with a learning disability do not commit crimes. Brier comments, "the available evidence suggests that problems with attention and impulsivity may be critical factors that, when present in combination with a learning disability, increase the likelihood of noncompliant, aggressive and antisocial behaviour." It may be that the dual effect of lead to contribute to a learning disorder and to problems with attention, impulsivity, and aggression is the reason why lead is so particularly associated with criminal activity.

With respect to FASD, as with lead toxicity, growing evidence suggests that nutrition is important both in terms of exacerbating the impact of alcohol and in terms of preventing its impact depending on the nutritional components. For example, the teratogenic effects of alcohol and low dietary zinc are synergistic and zinc supplementation during prenatal alcohol exposure may be able to reduce the damaging effects of alcohol on the learning defects (Summers et al. 2006,, 2008). This is of particular interest because a low zinc level is associated with an increased uptake of lead. Indeed, mothers of children with FASD have been found to have low calcium, low iron and low zinc all of which increase the absorption and the toxicity of lead. Thus, lead toxicity and alcohol toxicity may interact to make the learning defect worse. Lead toxicity may also increase the likelihood of a mother drinking alcohol. The interconnections between lead toxicity and FASD remain to be explored fully, but it may be that lead toxicity can exacerbate the impact of alcohol exposure during fetal life and that the dual impact of lead

exposure and FASD is such that the learning deficit from both combined is greater than either alone – perhaps synergistically so.

It is important to note that lead toxicity produces a profile of changes in the brain which include impulsivity and aggressiveness as well as a learning disability and that it is the dual impact of these changes together with the learning disability which appears to lead to criminality. As discussed above, it is very possible that other (non-lead associated) learning disabilities may also predispose individuals to committing crimes. Work in the United States and England to screen prison inmates for dyslexia as a step to helping them address their dyslexia, and thus reduce recidivism, follows this line of evidence (Cassidy and Cassidy 2018; Hewitt-Main 2020). Studies are needed of both dyslexia and lead levels in prisoners to assess to what extent lead is causative or facilitating of individuals committing crimes, and to what extent there may be other neurological or "brain health" conditions which lead to dyslexia, which may separately lead to criminality. It may well be that a broader effort to address learning disabilities, including those in individuals with traumatic brain injuries, is vital.

Of particular interest in this respect is the work of Caspi et al (2017). In this research project, children at age three years were given a 45 minute examination which included an "assessment of neurological soft signs, intelligence, receptive language, and motor skills and afterwards the examiners (having no prior knowledge of the child) rated each child's frustration tolerance; resistance; restlessness; impulsivity; and lack of persistence in reaching goals," to achieve a "global index of the three-year old's neurocognitive status. **Poor age-three brain health predicted a group of children which would have poor adult outcomes, including 81% of those with criminal convictions.** The authors did not look at lead levels in these children. But this may be a group of children where measuring lead levels could prove useful in identifying those who need a lead focused approached to their treatment.

Methamphetamine use and crime:

There has been a spike in property crime in Manitoba since 2016, with a dramatic increase in property crime in 2018. In 2019, Winnipeg saw the highest number of homicides ever recorded. Since property crime and homicides are crimes which have been shown to increase with lead exposure, it is important to ask whether the increase in crime in Winnipeg and Manitoba in 2018 and 2019, which has been correlated with the major increase in methamphetamine use, is related in any way to lead exposure. It is of course possible that it is completely unrelated to lead exposure. It might, for example, be solely due to the ineffective and slow approach of the provincial government to address the dramatic increase in methamphetamine use in Manitoba. Alternatively, it is possible that lead exposure is associated with an increased susceptibility to methamphetamine use, and that the increased crime results from the dual effect of lead and the availability of methamphetamine. Additional research is needed to assess this possibility.

Life Stress, Socioeconomic Circumstances and Crime:

Life circumstances have been related to crime. The relation of lead, crime and poverty has already been discussed. It is worth adding, however, that there is substantial evidence that prenatal or postnatal

stressors can amplify lead related alterations in learning; in impulsivity; in dysregulation of dopaminergic and glutaminergic pathways in the central nervous system; and in the effects of lead on the hypothalamic-pituitary-adrenal axis (Virgolini et al 2005, 2008; Graham et al 2011; Amos-Kroohs et al. 2016). Life stressors, including trauma, could similarly amplify the impact of lead on criminal activity.

From a broader socioeconomic status perspective, separating a lead effect from an SES effect is not easy. As Bellinger (2008) writes, "an association observed between SES and a health outcome might be an unrecognized lead effect. From a trans-generational perspective, a family's SES might reflect a lead-associated downward drift over time"

Blood lead levels in Indigenous people in Manitoba:

The author was unable to find information on blood lead levels in Indigenous people in Manitoba. The closest sampling has been done in First Nation communities in northern Ontario. Blood samples were collected in the fall of 1999 and the winter of 2000 in Fort Albany and Kashechewan from male and female adults in the western James Bay region of northern Ontario. The results showed that 18% of 196 Cree people had blood lead levels of $\geq$10 ug/dL (Tsuji et al 2008). The high blood lead levels were believed to be related to eating wild game hunted using lead shot. This is consistent with findings in British Columbia which showed high lead levels in beaver heart, Canada goose, deer and grouse meat (Chan et al. 2011). It is also possible that the lead could come from ducks or geese, which had been feeding in water bodies or marshes which had been contaminated by lead shot.

In 2018, concerns were raised again about the potential contamination from lead in ammunition and fishing gear (Ruff 2018).

While the imputed source of the lead in Indigenous people is from ammunition used in wild game, there is another potential source. Many of the residential schools where so many Indigenous children were taken had lead paint on their walls and lead in the ceiling tiles. Lead may also have been used in the pipes to supply water in the homes. Children spent a lot of time in these residential schools and it is conceivable that this could be the source of high lead levels in some Indigenous people.

The extent of lead paint in homes in Indigenous communities in Manitoba is uncertain. Whether any communities have lead water pipes is unknown, though most communities in northern Manitoba received water pipes after the use of lead pipes was discontinued. A comment on the potential relevance of the present report to the calls to action from the Truth and Reconciliation Commission of Canada is provided in Appendix 8.

The potential contribution of other metals:

Lead, cadmium and manganese have been found to be at significantly higher concentrations in the head hair of violent offenders compared to non-violent inmates or to controls (Masters et al 1998). Emissions of mercury and manganese have been found to be correlated with rates of youth adjudicated for criminal activity in Ohio (Haynes et al 2011). However, the documentation of the role of lead far exceeds that for any other metal. Additional comments on cadmium are in Appendix 12.

Crime Correlates:

Ellis et al (2019) have produced a synthesis of the many factors which have been found to correlate (positively or negatively) with crime. They list 79 factors which show a very strong correlation with crime (VSCC) and 37 more factors which show a strong correlation with crime (SCC). Lead is one of the factors which shows a very strong correlation with crime. Of particular interest, many of the factors which show a strong or very strong correlation with crime are factors which can result from lead exposure. Thus, as an example, lead exposure can result in a learning disability and difficulty reading. The presence of a learning disability correlates strongly with involvement in official crime or delinquency. As well, one of the very strong correlates with crime is reading ability, with those with greater reading ability being much less likely to be involved in official or self-reported criminal or delinquent behavior. Related to this, academic performance is very strongly correlated (negatively) with anti-social behavior and strongly correlated (negatively) with official crime/delinquency. As one of the effects of lead exposure is lower IQ as well as a learning disability, this strong negative correlation between academic performance and criminal activity could be a result (a variable which is dependent or the result of) of lead exposure.

As well the strong correlation of ADHD with unofficial offending and with official crime/delinquency, and the strong correlation of impulsivity/disinhibition with antisocial behavior and with official crime and delinquency, and the strong correlation of lack of self-control with unofficial offending behavior could all potentially be explained by the action of lead to promote to these behaviours.

In addition to the above, the strong and very strong correlations between criminal activity and alcohol use, substance abuse and mental illness could also potentially be in part the result of lead exposure having these impacts which are part of the lead to crime pathway discussed earlier.

In following this logic, many of the factors, which are very strongly correlated or strongly correlated with crime, may be strong correlates because they are part of the lead to crime pathway.

To what extent then, do we consider that lead exposure is a cause of crime? The evidence presented suggests that in some circumstances, as much as 50 to 90 % of crime or of the change in crime rates may be related to lead exposure. An analysis of the data from Christchurch, New Zealand (Figure 27) is consistent with lead being responsible for 74% of crime at the time of the study. At the same time, not everyone with a high blood lead level will commit a crime. Indeed, the study from Charlotte-Mecklenberg County show that even at the highest lead level, 85% of children did not commit a crime. This means that the lead level may set a framework in the brain which predisposes to crime, but that other factor(s) have a large impact on whether the framework is expressed – factors which likely include

whether the child is helped to overcome the learning disability, the dynamics of the situation in which the child is raised, whether the susceptibility of the child to develop a mental illness or a substance abuse is expressed etc. The many factors which correlate with criminal activity thus can be seen to play an important role in the lead to crime pathway.

The above is necessarily speculative. But it is important to present this in context so that people who have focused on one aspect of the road to criminality can see that the hypothesis being put forward here does not abandon the incredible contributions of many to understanding the causes of crime, but rather provides a potential framework for understanding what the role of lead may be in its contribution to the genesis of crime.

And lastly, the factors which are negatively correlated with crime may be looked on as possibilities for helping children who are found to have high lead levels. As already discussed, the intervention in the Charlotte-Mecklenburg Country study which successfully reversed the impact of lead, focused on reducing lead exposure, but it also focused on measures to help the family better raise the child including on nutrition and on a referral to medical and social supports to address specific learning and behavioural issues. In terms of nutrition, I have already mentioned the importance of adequate calcium, most commonly through milk, to decrease lead absorption. In addition, among the correlates with crime is a negative correlation of crime with omega-3 fatty acid intake. Studies have shown the importance of long chain omega three fatty acids to brain function. As Ellis et al (2019) say, “Nearly all of these experiments (in a table on page 331) have indicated that omega-3 supplements diminish offending behaviour among the experimental participants compared to the controls.” It may be that Omega-3 fatty acid supplements can be helpful as part of the nutritional recommendations for those with high blood lead levels. In a similar fashion, the emphasis on addressing academic achievement, learning and behavior in children found to have high lead levels may be an important part of the success we need in reducing crime.

If further research shows that crime in Manitoba is correlated with lead exposure, then there are substantive options for help for those who have been lead exposed. The measurement of blood lead levels can thus be seen to be an adjunct which can be helpful in the early detection and help for children at higher risk of becoming criminals as they age.

Lead and Dementia:

A growing body of evidence suggests that early childhood lead exposure or adult lead exposure may be a risk factor for dementia (Bakulski et al. 2012; Shih et al 2007; Reuben 2018). There are three lines of evidence.

A. **Animal studies**: Studies in Macaque monkeys exposed to lead early in life showed significantly greater "Alzheimer's Disease (AD) like pathology in the frontal cortex of lead-exposed monkeys". Mice exposed to lead early in life had "AD-like deficits in learning and memory that were accompanied by an over-expression of AD-related proteins",
B. **Adults exposed to lead**: Adults exposed to lead have been found to have an increased risk of Parkinson's Disease and to have evidence of cognitive decline in "AD-related domains, in verbal and visual memory, attention and general executive functioning, and in domains related to motor ability, manual dexterity and visuospatial ability" (Reuben 2018).
C. **Lead exposed children**: Individual case studies of children exposed to lead who were followed to adult-hood have been found to have, when they died, AD-like pathology in their brains. The evidence to date suggests that it is the cumulative lead exposure as measured by lead in the tibial bone that may best correlate with the level of and decline of cognitive function (Bandeen-Roche K 2009).

It will be important to better understand the extent to which there is a link between childhood and adult lead exposure and dementia. It will also be important to identify children and adults with high lead levels and to develop preventative approaches to decrease the potential for dementia later in life (Kosnett et al. 2007).

Even if the hypothesis that lead is a substantial cause or contributor to crime in Manitoba is not correct, there is still an urgent need to address high blood lead levels in children and adults.

It is, at this stage, important to emphasize that it is critical to address high blood levels in children and adults in Manitoba even if these are not direct or indirect causes of crime, because the impact of high lead levels on learning; behavior; on human potential; and on dementia; are sufficient alone to warrant a major effort to reduce lead exposure and lead toxicity by addressing the sources of exposure; the nutrition of individuals, and those impacts on the brain which are potentially reversible.

What do we need to do in Manitoba? - The Basic Preventative and Therapeutic Approach

The gold standard for the treatment of young children found to have high lead levels before age three has already been established through the work of Billings and Schnepel (2018). This same approach was found to have very positive effects in Chicago (Sampson and Winter 2018), both to help individuals and to reduce racial inequalities. The approach in Charlotte-Mecklenburg County involved lead remediation, nutrition, nutritional assessment and a nutritional plan, medical evaluation and a medical health plan, developmental surveillance and a public assistance referral. The approach in Chicago was similar except that in Chicago, the recommended schedule of testing was four blood lead tests by 36 months of age. As with other health interventions where a gold standard already exists, there is likely room for improvement, but any alternative needs to be tested to ensure it is as effective, or more effective, than the gold standard. It is to be noted that the American Association of Pediatrics (2020) says, "Most US children are at sufficient risk that they should have their blood lead concentration measured at least once." A similar recommendation should apply to Canadian children, at least until we can better know which children are most at risk. It is of note that blood lead monitoring and reporting has recently been recommended in Manitoba (Intrinsik 2019).

For children between the ages of 3 and 10, it is likely that an approach will be effective which models the gold standard for young children and which builds upon it incorporating the age of the child and the results of their current assessment.

For children who are older than age 10 or who are adults, there needs to be developed, implemented and tested a therapeutic approach or approaches which will be most effective. For youth, it is likely that special attention will be needed to the fact their brains are still developing and that the years from 11 to 25 will be of particular high risk in terms of school issues and the potential for delinquency and criminal activity. As with younger children, it is likely that the approach will need to address both the high blood lead and body lead burden and at the same time the impact of the lead on brain and psychological well being and on learning. Special attention may need to be taken with respect to the high risks for mental health and addictions issues. In Saskatchewan and Manitoba, the association of alcohol with criminal behaviour is very strong (Johnson 2019), and it is likely that specific measures to address this will be needed as part of an effort to reduce the likelihood of criminal behaviour. For adults, a similar combination of measures to address the lead levels and the psychological health and well-being are almost certain to be needed. For all ages, the involvement of public health in addressing the source of the high lead levels is needed coupled to efforts to ensure that these are addressed so that others are not affected.

Prevention of lead exposure remains the single most important measure when it comes to helping those with high blood lead levels. There cannot be shortcuts in this effort. The study in Charlotte-Mecklenburg County found that an adequate effort to reduce lead exposure in a home was expensive with an average cost of $7,291 US. Government funding was available for at least part of this lead remediation, and was an essential component for it to be effective. Half measures do not work. For

example partial replacement of a lead service line was not effective and full replacement was found to be necessary (Brown et al. 2011). Addressing lead in drinking water, in household dust, in lead-based paint and in residential soil are all important, as are looking for other potential sources (toys, spices etc.) as discussed earlier.

Chelation therapy and the treatment of youth and adults is discussed in Appendix 14.

In recognition of the impact a finding of high lead levels can have on an individual and a family a special message to those with high blood levels and their families is in Appendix 18.

The recognition that exposure to lead is a significant contributing factor to crime, will hopefully allow this information to be useful in the more precise diagnosis of the causes and improved treatment of those who perpetrate crime. As an example, there is a considerable body of work that looks at antisocial personalities and at psychopathy. There have been efforts to use instruments like the Hare Psychopathy Checklist –Revised (PCL-R) and the Violence Risk Appraisal Guide – revised (VRAG-R) to differentiate forms of psychopathy which are particularly associated with violent crime (Harris et al 2015). If there is a specific association of lead exposure with a particular form or forms of psychopathy, then this may enable improved diagnosis and improved treatment of these specific forms of psychopathy in a way that can reduce recidivism and reduce overall crime. It is possible that the work of Walsh (2012) in treating individuals with lead toxicity and other "nutrient" deficiencies is worth another look. Walsh's work has been largely overlooked, but his reported ability to achieve "symptom free" individuals in 53% of compliant assaultive subjects, could possibly be a harbinger of future improved treatment. At a time when Harris (2015) can state in his thorough review of violent crime "our assessment of the literature to date leads us to conclude that no treatments that reduce the violent recidivism of adult psychopathic offenders have yet been identified… If ever a problem called out for solution, it is this." The current report offers the possibility of a better path forward.

Solutions are needed not just for Manitoba and for Canada. Lead exposure and lead toxicity are global problems (Appendix 9). Prevention is highly cost effective (Appendix 10) and must be acted on with urgency. We are clearly not doing enough now (Appendix 11).

Recommendations: There is much more work to do.

Actions which are now needed to fully assess the extent of high blood levels in Manitoba, to decrease lead exposure as quickly as possible and to mitigate the impact of lead on those who have been exposed:

1) The provincial government should immediately fully implement the recommendation of the Canadian Pediatric Society - "Children found to have a blood lead level higher than 5 ug/dL (0.24 umol/L) should be investigated thoroughly and any identified exposure sources should be mitigated as soon as possible" (Canadian Pediatric Society -Buka and Herovet-Zeiber 2019). There should be a case management approach for children whose detected blood level is equal to or greater than 0.24 umol/L following the standard protocol used successfully in Charlotte-Mecklenberg County in North Carolina (Billings and Schnepel 2018) which included lead remediation, nutritional assessment; medical evaluation; developmental surveillance; and a public assistance referral. The nutritional assessment needs to ensure any iron deficiency anemia is addressed and must ensure that the child is receiving a nutritious diet which includes in part adequate calcium to decrease lead absorption, or is receiving specific calcium supplementation. Measures to consider could include the possibility of free milk supplements for children at schools in areas of lead exposure and/or a dietary supplement for all infants consisting of the requisite amounts of calcium, iron, zinc and vitamin D.
2) The provincial government should implement mandatory testing of blood lead levels of all children between one and two years of age, beginning in areas where known lead exposures are present including from industrial sources, from lead in water pipes, from lead in paint in older homes and from lead in wild game hunted with lead shot. Additional testing should be of children who have learning or behavioural difficulties including ADHD and conduct disorders, and those who are identified as higher risk for involvement in criminal activity including children in the care of child and family services, and all those who are arrested for criminal activity including for domestic and sexual violence and for homicide. The Province of Manitoba needs to follow through on its commitment to make blood lead levels reportable as has already been done in Quebec, and provide monthly reports on the total number of lead tests done and the number and proportion of tests which are at 0.24 umol/L (5 ug/dL) or higher.
3) The Chief Provincial Public Health Officer for Manitoba should implement as soon as possible a Manitoba Childhood Lead Poisoning Prevention Program designed to fully eliminate lead poisoning of children in Manitoba and to achieve blood lead levels of less than 5 ug/dL (0.24 umol/L) in all children in Manitoba. The program can be modelled on the effort undertaken by the CDC in the United States (2020b). The program, which should be funded by the provincial government, needs to be sufficient to address major sources of lead pollution as identified through the screening program. The program also needs to include funding from the province to help with remediation of homes where there are children with high lead levels. Any school-age child with a high lead level needs to have additional educational support at school to prevent future learning, behavioural and antisocial issue. The Chief Provincial Public Health Officer for Manitoba must establish and implement protocols and standards for the screening of children between the age of 1 and 3 and for the follow up of children with high blood lead levels, including the identification of sources of lead

exposure for individual children and the clean up, remediation or mitigation of such sources, the protocols and standards for nutritional assessment and support of such children and the protocols and standards for addressing learning and behavioural issues in such children.

4) The federal government must work closely with First Nation, Metis, and Inuit communities to develop and implement a plan to address lead contamination and high blood lead levels in these communities and provide the funding needed to implement screening, testing and remediation measures as soon as possible. As part of this effort the federal government should seriously consider banning all ammunition containing lead as has been recommended by Indigenous groups.
5) The federal government is urged to fully support a major investment to eliminate the problem of high lead levels in the water supply of Canadians. In partnership the province of Manitoba needs to implement a cost-effective plan to eliminate high lead levels in the water supply to Manitoba homes.
6) The Chief Provincial Public Health Officer for Manitoba should identify critically needed areas of research and testing needed in Manitoba and work with the Manitoba Centre for Health Policy (MCHP); Research Manitoba; and the Government of Manitoba to ensure the needed research is funded and is undertaken. Such research may include as examples:
    a. The study through the MCHP, of the locations of individuals with positive test results to provide a better understanding of the geographic distribution of high lead levels and areas of Manitoba which need special attention. This study can provide in depth information on the age of individuals and their locations related to various blood lead levels. Such a review is critically needed to be able to look in much more detail at the high blood lead levels which have been found in Manitoba.
    b. Research is needed to better understand whether lead contributes to dementia and to apply and test approaches to prevent the dementia should this be the case.
7) The provincial government working with Shared Health should develop and implement standard treatment approaches for youth and adults over age 10 for individuals found to have high blood lead levels. This should include addressing and refining the treatment of those with high lead levels who have been involved in violent acts. With the increasing understanding of the plasticity of the human brain, effective approaches may be found to help or ameliorate the situation of youth and adults with high lead levels.
8) The provincial government should consider developing and implementing a more effective approach in Manitoba to early detection and treatment of children with learning disabilities. Studies in New Zealand suggest that children can be effectively screened at age three to identify children at high risk of problems later on. Consideration should be given to implementing such a screening program for all three-year olds in Manitoba. To ensure children identified have adequate support the provincial government should provide public health care funding for psychological support by psychologists to help children who have learning or behavioural conditions including those who have been exposed to lead as documented by high blood levels.
9) The province should introduce a provincial public awareness program to alert Manitobans to the dangers of lead exposure. As part of this program , the province must in conjunction with the Manitoba Teachers Society and the Manitoba Schools Boards Association, include measures for the education of classroom teachers and of children themselves about the sources and risks of lead

exposure as part of school health interventions. As part of this awareness effort the Province of Manitoba must implement a program in conjunction with health care organizations such as Doctors Manitoba, the Manitoba Pediatric Society and the Association of Regulated Nurses of Manitoba, for the education of health care professionals with respect to lead.

10) The City of Winnipeg should review the level of orthophosphate used in Winnipeg's drinking water to ensure it is optimum.
11) The Province of Manitoba needs to review protocols and enforcement of protocols for industrial lead pollution and for recycling batteries, computers and other materials which contain lead.
12) Provincial and Municipal governments in Manitoba should work together with the Manitoba Real Estate Association and Winnipeg REALTORS to look at the optimum approach to identify homes with lead paint, and for notifying potential buyers.
13) The provincial government and/or the City of Winnipeg should follow the recommendations of Solademi and Thompson to consider improving enforcement and mandating the enclosure of the outdoor shredder in the St. Boniface Industrial area.
14) The province and the federal government need to review and make changes and improvements to environmental licensing and assessments (see Appendix 17).
15) The City of Winnipeg and the province of Manitoba need to review inspections and enforcements in relation to industrial sites to eliminate future lead contamination.
16) As the Auditor General of Manitoba has recommended in his Sept 2020 report on the provincial oversight of drinking water in Manitoba "the Province require all schools and childcare centres to promptly, and periodically thereafter, test for lead, and that the Department publicly report the results of these tests and corrective action taken.".

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Appendix 1: Dependent and independent variables in relation to lead and crime.

In an analysis of the association of lead and crime, as with other correlations, there is often an attempt to understand the proportion of the effect a variable or factor like lead exposure (measured as blood lead or as dentine lead, or bone lead) might have on crime. What is often done is an analysis which factors out in some fashion the effect of other variables. In this context it is critical to distinguish between dependent and independent variables. In the situation of concern in this report, a dependent (or intervening) variable is one in which lead has an effect on the specific variable and the change in that variable as a result of the lead exposure then has an impact to increase crime. An independent variable is one which is completely independent of the exposure to lead. To be complete, we also need to include "linked, precipitating variables" – variables which are linked to lead – in that they may be a precipitating or cause of high lead levels and act not after lead exposure, but rather act to cause lead exposure.

The Study of Fergusson in New Zealand:

The work of Fergusson et al in New Zealand looked at the association between lead and crime. The study used two measures of crime 1) self-reported violent/property offending and 2) officially recorded violence/property convictions. They divided the variables they studied into intervening (dependent) variables, and confounding variables. They chose as their intervening variables 1) leaving school without qualifications and 2) grade point averages, ages 11-13. These were chosen as intervening variables based on the known evidence that lead exposure is known to cause learning and behavioural disabilities and that such disabilities lead to poor performance in school and lower educational achievement.

Dependent (Intervening) variables:

In their article Fergusson et al comment: "*it may be proposed that the linkages between lead and crime arise from a causal chain process in which lead exposure leads to educational underachievement, with educational underachievement in turn increasing the risk of committing crimes. To test this theory, the analysis was extended to include measures of educational achievement as mediating variables. That analysis showed that control for the intervening role of educational variables explained much, but not all, of the association between lead and crime* ***after control for confounding****. These results are generally consistent with the conclusion that the adverse effects of childhood lead exposure on later crime may be largely, but not wholly, explained by the adverse effects of childhood lead exposure on educational achievement.*" Fergusson correctly concludes that the effect of lead on crime may be in part mediated by the effect of lead on school performance and on whether children and youth stay in school.

Linked precipitating variables:

Variables related to lead may be intervening variables which result from lead acting on the variable which then acts to increase crime. Alternatively, a variable may increase lead exposure. For example, living near a busy highway when leaded gasoline was being used or after it was used (as a result of

increased lead in the soil) or living near an industrial source of lead. Such variables are linked to lead exposure and so are not independent variables.

Independent variables:

In eliminating the use of dependent variables as "confounding" variables, it is important to use as confounding variables only those independent variables which are not either intervening variables and are not linked precipitating variables because eliminating such variables can inadvertently decrease the importance of the relationship between two variables – in the case of this report between lead and crime.

In their study, in addition to the above intervening (dependent) variables, Fergusson et al label several other variables as "confounding variables", and they use a primary model which eliminates the impact of these confounding variables. Their analysis in their words was expressed as follows: "*there was clear evidence of dose-response relationships between childhood exposure to lead and rates of officially recorded and self-reported violent and property crime …. These associations were explained, to some extent, by control for a series of confounding factors. However, even following control for confounding there was evidence of significant dose-response relationships between lead levels and later crime, suggesting a possible causal linkage in which early lead exposure led to increased risks of crime*." They go on to say "*While the present study suggests possible linkages between lead exposure and crime, these findings need to be placed in context. Specifically, the association between lead levels and crime after adjustment for confounding proved to be weak, and it was estimated that variations in lead levels explained less than 1% of the variance in individual rates of crime. This estimate contrasts sharply with claims based on contemporaneous data made by Nevin who reported that changes in lead levels explained 65-90% of the variance in violent crime in Western nations during the second half of the 20th century*."

In eliminating the impact of the "confounding" variables which they chose, and reporting the association between lead and crime as weak, Fergusson et al were making the assumption that the "confounding variables" were independent variables and were not dependent, intervening or linked precipitating variables.

However, in light of the work in this report, it now becomes clear that some or all of the variables chosen by Fergusson et al as "confounding" variables are very likely to be in fact either "intervening" variables or "precipitating" variables.

A brief description of each variable which Fergusson chose as a confounding variable and the potential relationship of the variable to lead and crime.

1) **Lead exposure factors**: traffic density to age 7. Increased traffic density is known to be associated with increased lead exposure. This therefore fits the category of a linked, precipitating variable which causes increased lead exposure. As such it is not an independent variable and should not be used as a confounding variable to determine the extent of the linkage between lead and crime.

2) **Socio-economic factors:** maternal age; paternal education level; average family living standards ages 0-8 years; average family income to age 5 years; school decile (relative deprivation) level. As discussed in this report, the impact of lead is intergenerational – that is a child exposed to lead and having a high lead level is very likely to have a mother and/or father exposed to lead. A mother or a father exposed to lead is more likely, as a result, to have a teenage pregnancy, to have low paternal education, to have a family income which is low and decreased family living standards when the child is aged 0-8. These are thus not independent variables, and are either linked precipitating variables – which lead to high lead exposure or are the result of lead exposure in the parents leading to criminal activity in the children and so could be considered intervening variables.
3) **Family functioning factors:** number of family changes to age 8 years; family exposure to stress, maternal use of punishment; parental illicit drug use; parental bonding. Adverse aspects of these factors could result from exposure of the parents to lead or from exposure of the child or both. These also are clearly not fully independent factors.
4) **Individual factors:** early onset cannabis use (by age 15); frequency of alcohol use at age 15. As discussed elsewhere in this report, there is reasonable evidence to suggest that lead exposure and high blood or body lead levels promote changes in the brain which increase the use of alcohol and drugs. These may thus be dependent, intervening factors and are not truly independent.

Based on the above analysis, the conclusion of Fergusson and his coworkers that the "*the association between lead levels and crime after adjustment for confounding proved to be weak"* has almost certainly significantly underestimated the actual association between lead and crime. An alternative approach to this issue (shown in Figure 25) and based on the data from Fergusson et al is consistent with the possibility that as much as 75% of the self-reported offences in their study could be related to the use of lead.

Crime correlates and their relationship to lead:

Ellis et al (2019) have looked extensively at factors which correlate with crime. It is helpful to look at these from the perspective of whether the factors, other than lead itself, are independent variables, are linked-precipitating variables or are dependent intervenor variables. This section will provide a summary of this information.

Ellis et al provide a summary of 116 factors which show either a very strong correlation with crime (VSCC) or a strong correlation with crime (SCC). The 79 factors scored as VSCC were based on the results of multiple studies (at least ten, and sometimes many more) all of which showed a significant correlation with crime. The 37 factors scored as SCC were similarly based on multiple studies in which at least 95% of the studies showed a significant correlation with crime.

As mentioned in the report, lead exposure and lead blood levels showed a very strong correlation with crime. This is summarized by Ellis et al as follows, "*without exception, studies have found positive correlations between lead levels in both the blood or in bone tissue and involvement in crime,*

delinquency or related antisocial behaviour. In addition to the studies of individuals, ecological studies have been conducted on violent crime and lead levels in the environment. These studies too have revealed positive correlations between homicide rates as well as other violent crime rates and lead exposure."

A careful evaluation of these studies shows that the remaining 115 factors break down into major groupings. Of interest, several of these major groups are of factors which are potential intervening factors – in the lead to crime pathway. Learning ability, reading ability, educational performance, school attendance, school discipline and intelligence all show strong or very strong correlations with crime, a fact with is consistent with the findings of Fergusson et al that educational performance is an intervening factor with lead causing changes in the brain leading to poor educational performance and such poor educational performance then being a intervening factor in the pathway by which lead influences and contributes to crime.

Similarly, poor self-control, impulsivity, and hyperactivity (as ADHD) showed very strong or strong correlations with crime, again consistent with these being intervening factors. Similarly, anti-social behaviour, family discord, poverty (assessed by the presence of welfare payments), mental illnesses (depression, suicidality), and substance abuse were among the groups of factors which showed very strong or strong correlations with crime, a finding consistent with the concepts shown in figures in the report in which these are suggested to be intervening factors triggered or promoted by lead ingestion along the pathway(s) by which lead promotes delinquent and/or criminal behaviour. The presence of these strong correlations with crime do not provide proof of the pathway(s) but rather are additional evidence consistent with the suggested potential pathway(s).

Appendix 2: Addressing the argument that the treatment program which reduced crime was the result of the impact of other factors than addressing lead.

The study of Billings and Schnepel (2018) looked at the effect of a treatment approach used for children with high lead levels, which included various interventions designed to address high blood lead levels. Because this intervention approach included improved nutrition, and in some cases learning and behavioural interventions, it would be possible to argue that the effect might have been the result of these interventions and not specifically to interventions to decrease the blood lead level. As I provide in detail below: 1) the nutritional and other measures were vital to addressing the blood lead levels 2) Medical interventions are increasingly multimodal and for good reasons and 3) Because of the success of these interventions to decrease crime and violent crime the measures have demonstrable success which suggests that the group of interventions are essential not just to help the children and families but also to decrease crime in a community. First, it is important to review in depth the interventions which were used.

The interventions used where children had high lead levels:

This treatment approach began with testing children's blood lead level at age 1 or 2 (Billings and Schnepel report these were normally done at the time of a regularly scheduled doctor's visit. Consistent with this a large number of the visits were clustered about 12, 18, and 24 months).

Children with a lead level which was high enough to be a level of concern were then put into two groups:

Group A: High lead level

Children in this group were provided with "nutritional and environmental information, a referral to the Special Supplemental Nutrition Program for Women, Infants and Children, an environmental history interview to identify sources of lead, and a referral to remediation programs for cases identified as high lead risk in the homes."

This process is described in more detail as follows: "The formal protocol for the standard intervention includes first taking a medical history regarding any symptoms or developmental problems along with previous blood lead measurements and family history of lead poisoning. The healthcare provider then performs an environmental history interview during which family members are asked about the age, condition, and ongoing remodeling or repainting of a child's primary residence, as well as other places where the child spends time (including secondary homes and childcare centres). The healthcare provider then determines whether a child is being exposed to lead-based paint hazards at any or all of these places. The environmental history also includes an inquiry about other sources of potential lead exposure."

"Based on the environment history interview, or a confirmatory test over 20 ug/dL [0.96 umol/L), a professional lead remediation team conducts a lead inspection at the child's home. This inspection leads to a determination of the home being lead-safe or in need of lead remediation. The provision of lead remediation services involves the removal of lead contaminants, which usually requires the replacement of windows and doors and the repainting of interior/exterior walls. During our sample time period, lead remediation was primarily funded through local government agencies, HUD-based lead remediation grants, nonprofits, and privately. The cost for lead remediation is not trivial with the average price for these repairs totaling $7,291 [US dollars]. "

"Since lead levels in the body are the result of a combination of lead exposure and the body's absorption of lead into the brain, nutrition can mitigate the effects of lead exposure. While the effectiveness of nutritional interventions is not established, research suggests that deficiencies in iron, calcium, protein, and zinc are related to blood lead levels and potentially increase vulnerability to negative effects of lead. A nutritional assessment includes taking a diet history with a focus on the intake of iron, vitamin C, calcium and zinc rich foods. The nutritional information is also used to assess the ingestion of non-food items as well as water sources that contain lead for the family. The healthcare provider inquires into participation in the Special Supplemental Nutrition Program for Women, Infants and Children or the Supplemental Nutrition Assistance Program and refers the family to these programs if they are not currently participating. For children with a confirmatory test over 20 ug/dL [0.96 umol.L], a medical examination is conducted with particular attention to the child's psychosocial and language development. In cases of developmental delays, a standardized developmental screening test is recommended, which offers referrals to an appropriate agency for further assessment."

Group B: Very high lead levels (over 15 ug/dL; [over 0.72 umol/L]) can initiate a more intensive intervention which included, "a mandatory home environmental investigation, a medical evaluation, and a detailed nutritional assessment." With progressive increases in blood lead level, the extent of intervention increases as more fully described in the article by Billings and Schnepel (2018).

Three reasons why this multimodal intervention approach is essential:

1) **The nutritional and other measures were vital to addressing the blood lead levels.** As detailed earlier in this report, nutrition has a major impact on the absorption of lead and on the blood lead level. This is a really important part of the whole program.
2) **Medical interventions are increasingly multimodal and for good reasons.** In many circumstances in health care it has been recognized that multimodal interventions are essential to prevention and treatment to the point that this is now standard practice in many areas of health care including cancer and cardiovascular disease.
3) **The interventions as described have shown demonstrable success in reducing crime, including particularly violent crime.** It is possible, based on the data provided in the paper by Billings and Schnepel, to make an estimate of the extent of crime and violent crime reduction which would have been seen had the intervention approach been provided to all children with an initial blood lead level of 5 ug/dL (0.24 umol/L) or more. These calculations for violent crime provide an estimated 51% reduction in overall violent crime based on the data provided in Figure 31 and

the numbers of children with the various initial blood lead levels (Figure 35). This is a very substantial impact and shows the importance of proceeding with the multimodal intervention as conduct in Charlotte-Mecklenberg County in North Carolina.

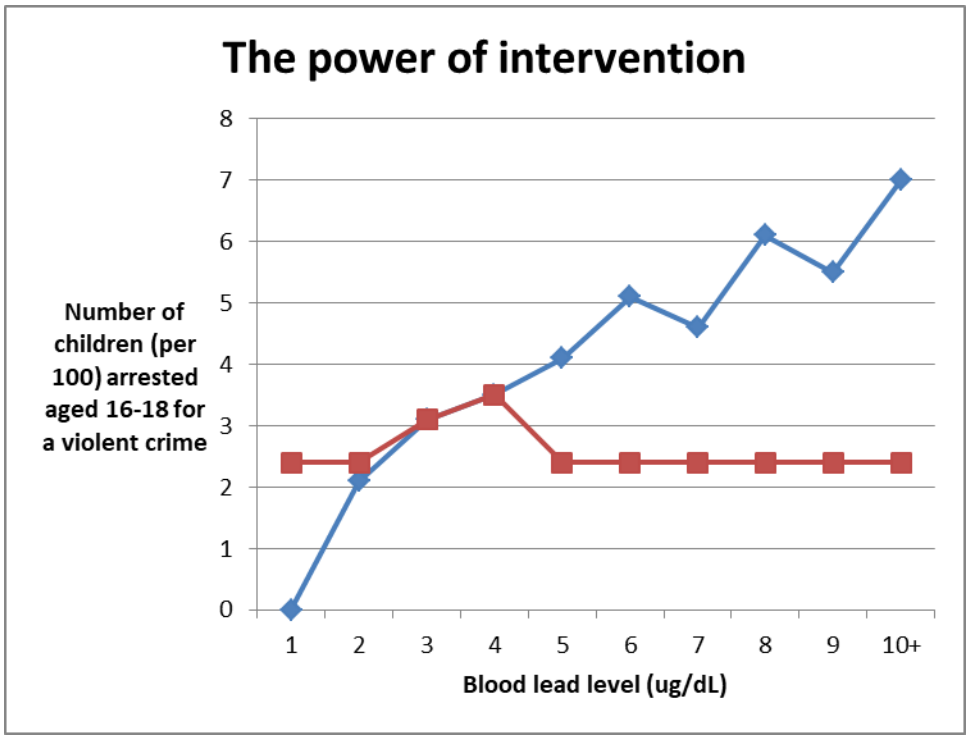

Figure 35: The blue diamonds reproduce the findings shown in Figure 31. The red squares show the level that violent crime was reduced to in children with a blood lead level of 10 ug/dL or above. The red squares thus show what is achievable in reducing crime if all children with a blood lead level of 5 ug/dL (0.24 umol/L) were provided the intervention used in Charlotte-Mecklenberg County. Based on information on the number of children provided in the Billings and Schnepel report, it is estimated that the achievable reduction in overall violent crime is about 50%.

Appendix 3: What proportion of violent crime in Manitoba is related to lead exposure?

A major question arising from this study is – What proportion of violent crime in Manitoba is directly or indirectly the result of lead exposure? The present report cannot adequately answer this question because we still need much information on the extent of lead exposure in Manitoba, and the relationship of this lead exposure to crime in our province. With Manitoba's violent crime rate being approximately double the Canadian average, it would be nice to identify a major cause for the increase in violent crime in Manitoba compared to the rest of Canada. If it were to turn out that half of the violent crime in Manitoba were related to lead exposure, we would have the ability to make changes to bring our violent crime rate down to the Canadian average. At the very least, the present report will provide fodder for discussion and debate and hopefully will provide a stimulus to look intensively at the role of lead in crime in Manitoba and the haunting issue of why Manitoba has such a high crime rate.

Appendix 4. Why is Manitoba worse when it comes to violent crime than other provinces?

This report began as part of a search for the reason for the high violent crime rate in Manitoba. What has emerged from the Concordia Institute for Investigative Journalism's collaborative study is that many other provinces have issues with lead in the water supply to communities. Until more information is available, it is not possible to ascertain whether Manitoba is worse than other provinces when it comes to lead contamination and lead exposure. However, one comparison, shown in Table 6 in the Government of Canada's *Final Human Health State of the Science Report on Lead* (2013) shows that in all six of the years from 2005-2010, the maximum lead levels measured in treated water exiting treatment facilities in Manitoba were at or above 9 ug/L whereas only 3 of21 reported maximums from other provinces were above this level.

Of interest is that the only other province which is close to Manitoba in terms of violent crime is Saskatchewan. Investigations in the last year have shown that Saskatchewan residents have some of the highest levels of lead in their drinking water in Canada (Wilson 2019). It is possible that Manitoba could be worse than Saskatchewan overall in terms of lead exposure when the exposure from lead using industries and lead paint and other sources are included. It is possible that the nutritional circumstances of Manitobans may also contribute to high lead levels in our province. Until more investigation is done, it will be hard to know.

Appendix 5: Orthophosphate added to drinking water to protect from lead exposure

Orthophosphate is added to Winnipeg's drinking water at a concentration of 2 mg of orthophosphate per liter to control the corrosion of lead service pipes delivering water and to dramatically reduce the amount of lead in the city's drinking water. This addition achieves a concentration of orthophosphate in Winnipeg's drinking water which averages 1.9 mg/L. Because the orthophosphate is added as phosphoric acid HPO4 which includes four oxygen molecules and one hydrogen molecule for every phosphorous molecule, the amount of phosphorous in Winnipeg's drinking water is only 0.682 mg/L (City of Winnipeg web site 2020). Cities adjust the concentration between 1.0 mg/L and 3.5 mg/L orthophosphate depending on the particular conditions of the water. There are many individual factors which can influence the situation in a particular city. It is of concern that 20% of Winnipeg homes with lead pipes are still reporting lead levels about the Canadian standard. It is possible that Winnipeg could adjust the orthophosphate level upwards toward the 3.5 mg/L level to reduce the proportion of homes with high lead levels in their drinking water (Michele Prevost personal communication 2020).

Of note here are the variables which have been listed as influencing the "lead solvency" – the extent to which water running through lead pipes will take up lead. As Troesken says, "even in well-controlled experiments on the chemistry of water and lead, it has been shown that small perturbations in a water's chemical and physical characteristics can significantly alter its lead-solvent powers. After water is distributed from its source, the following factors can influence lead solvency: water temperature; age, length, and diameter of the lead service pipe; biological activity within water mains and service pipes (such as decaying vegetation and the development of biofilms on the interior of pipes); decaying lime from cement mortar; and oxidation of large iron street mains. The lead solvency of source water can also vary depending on the season, atmospheric pollution levels, and the presence of biological and chemical agents." With the variety of factors mentioned, each city will have to do testing on its own system. Winnipeg does such testing. However, in view of the fact that 20% of homes with lead pipes are above current Canadian guidelines, it is important to review the situation in Winnipeg to see if adjustments can reduce the number of homes with high lead levels in their water. As stated above, there appears to be room to increase the concentration of orthophosphate in the City of Winnipeg's water supply as one option.

Appendix 6: Non-neurological effects of lead toxicity:

The neurological effects of lead are broad and can include (on top of the effects on learning and behaviour described earlier) symptoms such as headaches, irritability, lethargy, convulsions, muscle weakness, ataxia, tremors and paralysis. But it is also important to identify and know the symptoms of lead exposure and the impact of lead on other systems. The reason for this is to put the impact of lead on the whole body in perspective and to provide information which shows that the importance of reducing lead exposure reaches far beyond its impact on the brain and the nervous system.

Symptoms: The UNICEF-Pure Earth report (Rees and Fuller et al 2020) provides a helpful summary of the signs and symptoms of lead poisoning: The report says, "**A challenge with childhood lead poisoning is that it is typically insidious. At low to moderate levels of exposure and blood lead levels, there are typically no symptoms at all and no physical signs that are apparent to a clinician.** At moderate to high levels of exposure, children may complain of a variety of non-specific symptoms, such as headaches, abdominal pain, dullness, loss of memory, poor attention, loss or appetite or constipation. The impacts of lead poisoning on neurological processes and the central nervous system may result in indications of clumsiness, agitation, or decreased activity and drowsiness which can proceed to vomiting, stupor and convulsions in more severe cases."

Major non-neurological health effects: The Government of Canada's report on lead (2013) focuses on effects on the cardiovascular system, the renal system (kidneys) and the reproductive system. I will also note observations related to the gastrointestinal system and cancer.

The Cardiovascular System: Lead has been associated with an increase in cardiovascular mortality, starting at a blood lead concentration of 3.6 ug/dL (Menke et al 2006). The impact of this is described in a study by Schwartz (1991) which finds: "The results suggest that a halving of the population mean blood lead level would reduce myocardial infarctions by approximately 24,000 events per year [in the United States] and the incidence of all cardiovascular disease by over 100,000. These numbers suggest a small attributable risk compared to the vast incidence of cardiovascular disease in the U.S., but a large attributable risk compared to most environmental toxins." Lead also has a general effect to increase blood pressure, especially during pregnancy, and to increase peripheral vascular resistance and the risk of peripheral vascular disease. (Government of Canada 2013).

The Renal System: Lead exposure has been associated with reduced kidney function, measured as a reduced creatinine clearance, increased serum creatinine and increased chronic kidney disease - with effects found at 2.2 ug/dL and above (Akesson et al 2005; Muntner et al. 2003).

The Reproductive System: Lead exposure has been found to be associated with delayed puberty in females and males, with an increased time to pregnancy, decreased sperm concentrations, an increased risk of infertility and a decrease in gestational length and an increased risk of pre-term delivery (Government of Canada 2013). It has also been associated with hypertension during pregnancy and increased preeclampsia and eclampsia (Jameil 2014; Troeksen 2006), and with increased infant mortality (Troesken 2006).

The Gastrointestinal System: One of the well-described effects of lead, in particular lead in a water supply, is abdominal pain or colic (Troesken 2006).

Cancer: "Overall, there is only weak evidence associating lead with cancer; the most likely candidates are lung cancer, stomach cancer, and gliomas" (Steenland and Foffetta 2000). The International Agency for Research on Cancer has classified inorganic lead as probably carcinogenic to humans. They base this on the fact that there is limited evidence of carcinogenicity to humans, but there is sufficient evidence of carcinogenicity in animals (Rees and Fuller et al 2020). There have been concerns about high lead levels in the Weston School area being associated with cancer (CBC News 2018).

Appendix 7: The biochemical and cellular mechanism(s) of lead's action.

A variety of studies have provided information on the mechanism of lead's action at a cellular and subcellular level.

Calcium, zinc and thiol groups: First lead is similar in certain properties to calcium which is critical to many cellular functions particular for sending messages or signals within and between cells. Because of lead's similarity to calcium it can in some cases mimic calcium and in other cases displace and inhibit the actions of calcium. Through these actions, lead can disrupt neurotransmitter function and impact neurodevelopment, impair learning, attention and memory.

Lead can also bind to certain biological molecules including the thiol (sulfhydryl) and amide groups of enzymes. As a result of this action, or the interaction with calcium or zinc dependent processes, lead can disrupt or alter enzyme function.

Neurotransmitters: Evidence supports the interference by lead with the binding of the proteins synaptotagmin and syntaxin which are important for neurotransmitter release (Troesken 2006).

Myelin synthesis: Another biochemical mechanism which has been identified for lead's effects on the brain is the impact of lead to decrease the activity of an enzyme integral to myelin synthesis and to destroy myelin sheaths (Lidsky and Schneider 2003). The impact of lead may be largest in early childhood, before age two, and just before puberty when there are important increases in myelin deposition. The latter may be particularly relevant to the development of impulse control during adolescence when there is ordinarily a considerable increase in myelin in the frontal lobes which are important for the development of impulse control (National Institute of Mental Health 2001). Certain of the impacts of lead on brain function may be irreversible, but the impact on neurotransmission may be reversible if the exposure to lead is ended (Silbergeld 1992). The latter may be very important in our ability to help those who have been exposed to lead (see below). In addition to the observations in the body of this report, certain additional potential mechanisms of the action of lead are worthy of note.

Delta-aminolevulinic acid dehydratase (ALAD): ALAD is an enzyme which is important in the process to produce hemoglobin, the protein in red blood cells which binds oxygen. It is activated by zinc. Lead competes for zinc and inhibits the enzyme. As Troeksen (2006) comments: "increasing the blood-lead level from 0 to 15 ug/dL is associated with a 50 percent reduction in ALAD activity. As ALAD activity is decreased, the concentration of its precursor molecule, aminolevulinic acid (ALA), in the bloodstream increases. Undue levels of ALA produce many of lead's symptoms, including lead colic (stomach cramps and constipation), brain swelling and pressure headaches, sleeplessness and restlessness. Increased ALA levels might also account for some of the behavioural disorders associated with lead poisoning. "

Protein Kinase C: Protein Kinase C is an enzyme which is very important for intracellular signaling or messaging. Protein Kinase C can be activated by calcium and lead appears to interact with Protein

Kinase C to disrupt the normal calcium activation process. This may be important in the effect of lead on learning and memory (Godwin 2001).

Additional information related to the mechanism of action may be derived from studies of genetics (see Appendix 14).

Appendix 8: Potential relevance to the calls to action from the Truth and Reconciliation Commission of Canada.

We live in a time of reconciliation following the report of the Truth and Reconciliation Commission of Canada. Since there are far too high a proportion of Indigenous people in Manitoba's and Canada's child welfare system and correctional institutions, this report has potential relevance to several of the calls to action of the Truth and Reconciliation Commission of Canada.

To date there is only a small amount of evidence that some Indigenous people in Canada have high blood lead levels. These studies are referenced in the section of the report on Indigenous People. Thus, the relevance of the findings of this report to Indigenous people in Canada is uncertain. Nevertheless if a few, some, or many Indigenous people, particularly mothers, fathers and children, have high blood lead levels and if this is contributing to difficulties in learning, in behaviour, in school attendance, with mental illness, with substance abuse and with being a perpetrator or a victim of criminal activity, then this may have relevance to the following calls to action.

Call to Action 1: "We call upon the federal, provincial, territorial, and Aboriginal governments to commit to reducing the number of Aboriginal children in care": If as in Pennsylvania, a few, some or many Indigenous children in care or their parents have high blood lead levels, this report may be relevant in calling for measures to decrease high blood lead levels in children and adults and for measures to improve social supports for them.

Call to Action 7: "We call upon the federal government to develop with Aboriginal groups a joint strategy to eliminate educational and employment gaps between Aboriginal and non-Aboriginal Canadians". If a few, some, or many Indigenous children and/or adults have high lead levels, this report may be relevant in calling for measures to decrease high blood levels in children and adults and to address learning and behavioural issues in such children and/or adults.

Call to Action 19: We call upon the federal government, in consultation with Aboriginal peoples, to establish measurable goals to identify and close the gaps in health outcomes between Aboriginal and non-Aboriginal communities: If a few, some, or many Indigenous children and/or adults have high blood lead levels, this report may be relevant in calling for measures to address health issues related to lead which may be being addressed inadequately currently.

Call to Action 33: We call upon the federal, provincial, and territorial governments to recognize as a high priority the need to address and prevent Fetal Alcohol Spectrum Disorder (FASD): FASD is discussed in this report and to the extent that FASD and lead exposure may interact and to the extent that lead exposure may predispose to substance abuse, it is possible that this report is relevant to this call to action when it calls for measures to reduce lead exposure and to include the provision of additional social and educational supports for those with high lead levels.

Call to Action 34: We call upon the governments of Canada, the provinces, and territories to undertake reforms to the criminal justice system to better address the needs of offenders with Fetal

Alcohol Spectrum Disorder (FASD): To the extent that there is any interaction between FASD and lead exposure and lead toxicity, this report may be relevant in its recommendations for measures to reduce lead exposure and to include the provision of additional social and educational supports for those with high lead levels who have learning or behaviour issues or mental health or substance abuse issues.

Call to Action 38: We call upon the federal, provincial, territorial, and Aboriginal governments to commit to eliminating the overrepresentation of Aboriginal youth in custody over the next decade: To the extent that Aboriginal youth with high lead levels are in custody, this report may be relevant in recommending action to reduce the exposure of Manitobans to lead and to follow the approach used in Charlotte-Mecklenberg county to address high lead levels found in children age 1 and 2.

Call to Action 40: We call on all levels of government, in collaboration with Aboriginal people, to create adequately funded and accessible Aboriginal-specific victim programs and services with appropriate evaluation mechanisms. As discussed earlier in this report, Emer et al (2000) found in Milwaukee that "The proportion of firearm violence attributable to blood lead ≥5 μg/dL was 56% for perpetration and 51% for victimization." If there is a relationship between high blood lead levels and victimization, this report may have relevance to this call to action.

Call to Action 55: We call upon all levels of government to provide annual reports or any current data requested by the National Council for Reconciliation so that it can report on the progress towards reconciliation: If there are a few, some or many Indigenous people with high lead levels, and this is relevant to calls to action 1,7,19, 33, 34, 38, 40 or 65, then these matters should be included in such annual reports.

Call to Action 65: We call upon the federal government, through the Social Sciences and Humanities Research Council, and in collaboration with Aboriginal peoples, post-secondary institutions and educators, and the National Centre for Truth and Reconciliation and its partner institutions, to establish a national research program with multi-year funding to advance understanding of reconciliation. To the extent that there are a few, some or many Indigenous people with high lead levels and that this is in anyway linked to calls to action 1,7,19,33,38,40 or 65, then additional research may well be needed.

Appendix 9: A Global Overview:

A recent report from UNICEF and Pure Earth Blacksmith Institute provides evidence that "around 1 in 3 children – up to approximately 800 million globally – have blood lead levels at or above 5 micrograms per decilitre (ug/dL) a level that the US Centres for Disease Control and Prevention (CDC) have determined is cause for action and which the World Health Organization says may be associated with decreased intelligence in children, behavioural difficulties and learning problems." (Rees, Fuller et al. 2020)

Further, globally, in 2019, it has been estimated that lead exposure accounted for 902,000 deaths and 21.7 million years of healthy lives lost (Disability Adjusted Lived Lost – DALY's) (Institute for Health Metrics and Evaluation 2019). To focus in further, lead exposure has been calculated to account for 63.2% of the global burden of idiopathic developmental intellectual disability, 10.3% of the global burden of hypertensive heart disease, 6.2 % of the global burden of stroke, 5.6% of the global burden of ischemic heart disease and 3.6% of the global burden of chronic kidney disease (Stanaway et al. 2017, Institute for Health Metrics and Evaluation 2020). And this does not include any estimate of the global burden of violent crime, substance abuse and mental health conditions. Sadly the global death rate attributable to lead is continuing to increase – and is now 21% higher than in 1990.

The UNICEF-Pure Earth report goes on to say "**The unequivocal conclusion of this research is that children around the world are being poisoned by lead on a massive and previously unrecognized scale**." The report notes the impact of lead on children's IQ scores and notes "These reductions in IQ undermine children's future potential and diminish their prospects. Widespread cognitive declines across large numbers in a city or country result in declines in creative and economic productivity across entire societies."

The report mentions that this exposure to lead is primarily a result of human activity, and that lead in the human body is now 500-1000 times greater than it was in pre-industrial times (Flegal and Smith 1992).

The report calls for "an urgent international response", and goes on to make a series of recommendations for action.

The UNICEL-Pure Earth report outlines a six-point approach to addressing lead pollution and human lead exposure. This includes 1) improving monitoring and reporting systems, 2) implementing prevention and control measures, 3) management, treatment and remediation, 4) public awareness and behavioural change, 5) Legislation and Policy and 6) Global and regional action.

It is important to push for action globally as well as locally. Part of the reason for this is the potential for ceramics to be brought into Manitoba by Manitobans visiting places like Mexico where lead has long been used for glazes on ceramics. Part of the reason is to limit the potential for spices and cosmetics which are imported to contain lead. As good as we may be in Canada in preventing the importation of

lead contaminated goods, it will help if there is an international effort so that the problem can be addressed at its source.

As the UNICEF-Pure Earth report says global action “includes creating global standard units of measure to verify and track the results of pollution intervention, on public health, the environment, and local economies; building an international registry of anonymized results of blood lead level studies; creating international standards and norms around recycling and transportation of used lead-acid batteries, including transboundary movement; establishing partnerships that mobilize resources and technical assistance, including from the private sector and industry, to address unsound used lead-acid batteries recycling and other lead sources; and fostering research in areas where there are evidence/research gaps.”

Appendix 10: Reasons to reject the argument that Manitoba is doing enough to address lead and its impact in our province.

Some may argue that Manitoba is doing enough with respect to lead. For example, it is 20 years since the addition of orthophosphate to Winnipeg's water. Perhaps we can expect a rapid decline in crime rates in the next few years given the lag time of 20 to 22 years from exposure to when crime occurs. This would be nice, but it is not likely to be true given that 20% of Winnipeg's water samples in areas with lead pipes show high levels of lead. There are also other sources of lead. It is for this reason that it will be very important to have active public health involvement to track down the sources of lead, just as public health is now tracking down people's contacts to find the sources of exposure to the COVID-19 virus. We will need a very active effort – following the recommendations in this report - in order to fully address the lead issues in Manitoba, to improve the lives of children and adults with lead exposure and to decrease crime to lower levels.

Appendix 11: Comments and Questions in the Manitoba Legislature on Lead Exposure, ADHD, Mental Illness and Crime

Manitoba Legislature - Hansard Nov 5, 2018

Speaking on changes to the Environment Act introduced by the Pallister government to eliminate the need for notice of important environmental information in local newspapers

Hon. Jon Gerrard (River Heights): There's some recent information about lead levels–high lead levels–in Weston, in St. Boniface. You know, it's apparent that not only does accurate information need to get to people in the community, but people need to be informed at community meetings. People need to know what to do. They are wondering, they are saying, well, you know, there were results which show that there were very high lead levels in 1988. That information has been hidden by consecutive governments for 30 years.

People need to have a government which is ready to be open, to end this era of cover-up and make sure that the information is there for people, and to make sure people know, you know, what do we do? Can we eat the vegetables in our garden? What do we have to do so that what we plant next year is okay if what we planted last year is not? These are pretty fundamental and close-to-home kind of issues, and it's pretty important that there be public information on this.

Hansard Nov 28, 2018:

Response to 2018 Throne Speech

Hon Jon. Gerrard (River Heights): We have numerous contaminated sites: Weston, St. Boniface–new results almost every day showing continued contamination. It's unbelievable the neglect shown by previous governments dating back to 1988, neglect with respect to the prevention of health issues in citizens in the area.

Lead's been associated with neurological consequences as well as cancer. It is important that we are doing better in this–addressing contaminated sites more quickly and notifying residents more quickly.

Hansard – Dec 4, 2018 – Oral Questions

Lead Contamination in Soil - Health Effects on Children

Hon. Jon Gerrard (River Heights): Madam Speaker, successive NDP and PC governments have known for decades of dangerous levels of lead in neighbourhoods across Winnipeg, including St. Boniface, Point Douglas and Weston.

We know where the contamination is. We know there can be serious health impacts from lead as well as other metals. The Minister of Sustainable Development has dropped the ball on this issue. It now falls to the Minister of Health.

We know there's been lead contamination. The question is whether this government has asked for any assessment of the health of children and youth in the contaminated areas.

Hon. Rochelle Squires (Minister of Sustainable Development): I'd like to correct the member's preamble where he stated that the Minister of Health is taking action now on matters of health. And, well, that's exactly what he is doing.

We are putting back public health–*[interjection]*

Madam Speaker: Order.

Ms. Squires: –in terms of the Health Minister is now responsible for matters of public health.

My department is responsible for matters of environment, and we work together as a team. That is exactly the way it should be. The NDP reversed direction. They pulled public health away from the environmental process so that the environmentalists were offering public health. It never should have been that way, and we're setting it right. We're working as a team and getting action for Manitobans.

Madam Speaker: The honourable member for River Heights, on a supplementary question.

Mr. Gerrard: Madam Speaker, the Manitoba Liberal caucus submitted a request to determine if areas of St. Boniface impacted by contamination were showing different levels of illness. Children and youth living in postal zones around the St. Boniface contaminated area show higher levels of prescriptions for drugs related to mental health than in the rest of Winnipeg and in Manitoba. I table that report.

These findings are of concern. They could indicate that children and youth in that area may be more likely to have ADHD, which can be treated with such medications.

Will the minister and his department investigate these findings and study whether the health of children and youth in St. Boniface, Point Douglas and Weston and other neighbourhoods have been adversely affected by years of government inaction?

Ms. Squires: Speaking of years of inaction by the government, that was under the NDP. They hid the report. In 2007, they had a report. In fact, they had a draft press release.

In fact, they had that press release ready to go, and their minister said, no, we don't want to put this out; it might affect the election that we're going into. So they buried the results. From 2011 all the way until 2017, that information was concealed.

Our government is taking action–I'd also like to table the results from the most recent analysis that my department undertook–and that is exactly what we're going to do. We're going to continue to work on this issue so that we can ensure Manitobans have a safe, clean environment for all.

Madam Speaker: The honourable member for River Heights, on a final supplementary.

Request to Release Reports

Mr. Gerrard: Madam Speaker, we've heard from people in affected neighbourhoods. They don't want finger pointing, they want action to make them safe, and to clean up. We can't continue to have a culture of inaction when tests showing lead contamination were known and withheld from the public. *[interjection]*

Madam Speaker: Order.

Mr. Gerrard: There needs to be a full investigation of why the information remained hidden for so long. This is a matter of serious public concern, and the answers are available but out of reach because they're available only in the advice to ministers and Cabinet confidences.

Will the Premier and the Leader of the Official Opposition (Mr. Kinew) give consent to release the relevant documents from Cabinet confidence so a proper investigation can happen?

Hon. Brian Pallister (Premier): So let's be clear: the member doesn't want finger pointing, but he wants a full investigation and points the finger at the previous government, Madam Speaker, and the current government.

This is the typical Liberal approach: blame everybody and don't take responsibility. Madam Speaker, this government takes responsibility.

The reality is soil tests were conducted 10 years ago. The reality is the results were covered up by the previous administration. The reality is the results were released; they were made public. The reality is retesting was ordered by the minister. The reality is the minister went the extra mile to get the information to the people of the area.

The fact is the people of Wolseley, Logan, Minto, St. B and Point Douglas were not protected by the previous government, but they are by this one.

Some Honourable Members: Oh, oh.

Hansard March 21, 2019 – Oral Questions

Lead Contamination in Soil - Testing of Residents Gardens

Hon. Jon Gerrard (River Heights): Madam Speaker, Janice Clarke lives near Weston School. She and others are concerned that the minister's report, tabled last week, shows that levels of lead in the surface soil at Weston School are still too high and are still above acceptable levels.

Her home is next door to one in which the garden and its soil were remediated a number of years ago. However, her home never had its garden remediated. She would very much like to grow and eat vegetables, but is uncertain about whether it is safe.

Would the minister provide for the testing of gardens like Ms. Clarke's, who lives in an area with proven high lead levels where there is uncertainty as to their current status?

Hon. Rochelle Squires (Minister of Sustainable Development): Our government takes the issue of lead in the natural environment very seriously, as do many other jurisdictions throughout North America that are challenged with this very task that we are facing today of increased exposure of lead in our natural environment.

That is why we felt–important to release a lot information. We've released the 1988 report that was covered up by a former NDP Premier, Howard Pawley. We released the results that were covered up by the former NDP government in 2008 and 2009 that revealed higher incidence of lead in the constituencies of Point Douglas, Minto, Wolseley and Logan, and we will continue to report on this as we're moving forward and working to ensure safety for all Manitobans.

Madam Speaker: The honourable member for River Heights, on a supplementary question.

Mr. Gerrard: Madam Speaker, there's lots of evidence of high lead levels, but there's no advice in terms of what people should actually do.

For many years, the presence of high lead levels in the Weston and north Point Douglas has been dealt with in a way that's unsatisfactory in that residents have been uncertain about their status and continue to be concerned about their situation.

Is the minister going to handle the current situation so that residents will have greater clarity with respect to how to proceed? For example, whether they can or should plant gardens? What criteria should residents use in making a decision about planting gardens and growing vegetables?

Ms. Squires: I do have to address some of the inaccuracies put forward by this Liberal member in his preamble.

We have taken strong action. In fact, last July our department knocked on the doors of people who lived in the constituency of St. Boniface to alert them to the exceedances of lead in their yards and gave them information on how to protect them–their gardens, what to do with the vegetables. We've been out no less than three public conferences that we have held in conjunction with public health to make sure that people have the right information they need to keep themselves safe if they are in a zone that is–got exceedances of lead in the natural environment.

We are taking action. Where the former NDP government failed, we're getting it right.

Madam Speaker: The honourable member for River Heights, on a final supplementary.

Mental and Physical Health

Mr. Gerrard: The minister is not tabling the information today or distributing it. Ms. Clarke hasn't seen this.

Madam Speaker, lead is known to have adverse effects on the brain and mental health and on physical health. I table today information which indicates that Weston and north Point Douglas areas have a higher incidence of various mental health conditions than the rest of the city of Winnipeg.

Will the government commission an in-depth study to look at the relationship between the high lead levels found in Weston and north Point Douglas areas, and the mental and physical health status of people and their children living in these parts of Winnipeg?

Ms. Squires: Well, I think it's absolutely shameful that this member would come up and make false allegations and make very unsubstantiated health claims for people who are dealing with real mental illness, real issues, and try to purport that that is a result of lead in their soil. That is absolutely unsubstantiated. We've had absolutely no public health officers, no medical officers, no one is saying that but the member for River Heights, and he should get up and apologize for putting such–inaccurate information on the record just to fear monger and score political points. Shame on him.

Hansard October 2, 2019 – Health Estimates

Mr. Gerrard: Lead has been a particular issue in some areas of Winnipeg. In testing of the situation in Flin Flon, there were a number of children who were tested around the playing fields or the schools which were affected by high lead levels and some of those children were found to have high lead levels.

So I'm asking the minister whether in fact there has been any testing of children or adults in areas around the areas in Winnipeg and Weston School and St. Boniface where there have been high lead levels to see if the children or adults have got high lead levels and to see if this is a problem.

Mr. Friesen: Health and public health has, of course, worked very collaboratively on this issue with Sustainable Development when it comes to the lead-level testing in soil the–to the which the member refers. I'm pleased to see NDP members in the Chamber, because, of course, they were complicit in a cover-up when it came to these schoolyards. The members of the NDP knew and took deliberate steps to not disclose levels of lead in the soil at the Weston School playground.

Members of Cabinet at that time interfered–and I will say this–interfered in a process to disclose to Manitobans–a website had been developed to disclose to Manitobans these dangerous or over levels of lead in soil. And that website was unceremoniously turned down before it ever went live. I am shocked that the media in this province has not paid more attention to the issue.

To the member's particular concerns, whether justice will ever be done on that account for the people who live in those areas, I don't know. We have worked in collaboration. It was our government who disclosed these levels. It is our government, under the direction of the Minister for Sustainable Development who undertook to additionally study these levels. It is our minister who undertook to disclose those levels in a proactive way to Manitobans. We have worked collaboratively.

The public held–the Chief Provincial Public Health Officer who was acting told me that there is no imminent threat; there's no dangerous level in this area, at the school ground or community ground. I asked that individual if he would have helped–felt comfortable for his children to go play in that playground, and he said, absolutely and without qualification.

To the member's questions about whether in future there should be more substantive work undertaken to test for lead levels in people, well, I think we would have to be careful to develop a evidence-based and scientific-based examination of this before we assign causality. We would have to understand what other contaminants in the area of the city there might be unrelated to the levels in excess that we saw at these hotspots.

The member also understands, as the–I know the Minister of Sustainable Development (Ms. Squires) will be able to provide further clarification of these matters when she is herself in the Committee of Supply. But we know that the work to denotate the locations of testing going back to the 1990s, I believe, when the first testing was undertaken–could have been the '90s–it was not exceptionally scientific in the location.

We know how critically important that is now in modern soil testing. So we're essentially going back to site and trying to decide, on the basis of landmarks, where we should be taking the next soil site–sample from. And that's very unprecise. Not to say that further work couldn't be undertaken, but I would direct that member to make further questions to the Minister of Sustainable Development, who, I know, will only be too happy to answer those questions because she herself really took this issue seriously, undertook to do the work to undo the calamity of the cover-up of the NDP in respect to this file.

Hansard October 10, 2019 – Oral Question

Violent Crime Statistics Lead Exposure

Hon. Jon Gerrard (River Heights): Manitoba has a disturbingly high level of violent crime. Under the present Conservative government the violent Crime Severity Index has risen by more than 30 points to reach 169.8; no other province has seen anything comparable. Manitoba may have a large increase in crime under this government because the government has done little to address poverty, homelessness, mental health or addictions. Alternatively, as I table, increasing evidence links violent crime to lead exposure, and lead exposure details have been covered up for years in Manitoba. Will the government ensure action is taken rather than more study and stall?

Hon. Cliff Cullen (Minister of Justice and Attorney General): Well, Madam Speaker, while the member's reading the information pertaining to the Chief Medical Examiner, I will also send him over a copy of our Manitoba's Policing and Public Safety Strategy. This strategy was developed in consultation with police forces across Manitoba and stakeholders. Now, we know we are taking the collaborative approach by working with police agencies across the province. We know what the NDP platform is: the NDP platform was to get rid of the RCMP here in Manitoba. That is not our approach. Our approach is a collaborative approach, and we're working through this strategy. We're working with all stakeholders to provide public safety to all Manitobans.

Hansard November 22, 2019

Response to the Throne Speech

Hon. Jon Gerrard (River Heights): Toxic chemicals are known to be associated with increases in violent crime, and one of the most carefully studied in this context is lead. And we have had problems with lead contamination in this province. And sadly, too often they have been covered up and they are still not being adequately addressed and they are not even mentioned in this Throne Speech.

Appendix 12: Cadmium:

Cadmium is discussed briefly here because it is sometimes linked with lead as a neurotoxin, and because, in a U.S. Army experiment, 6 kilograms of zinc cadmium sulfide were sprayed on Winnipeg in 1953 from July 9 to August 1 (Ferreira 2017, Martino-Taylor 2017). St Louis, in the United States, is another city where cadmium was sprayed (Martino-Taylor 2017, Johnson W 2020). St. Louis, like Winnipeg has a high crime rate. As Walter Johnson (2020) notes "St. Louis today has the highest murder rate in the United States (65.8 per 100,000, around four times the rate in Chicago, and thirteenth highest in the world)". Both Winnipeg and St. Louis were the site of significant lead smelter activity. Indeed in 1840, St. Louis had the largest smelting plant in the U.S. and in 1847 it was noted that there were "immense piles of lead" on the quay along the Mississippi River at St. Louis (Johnson W 2020). Thus, because of the documented long term lead exposure in the two cities, and because the evidence for a link between lead and crime is much stronger than the evidence for a link between cadmium and crime, it is much more likely that the high crime rates in Winnipeg and St. Louis are both related to high lead levels in the blood of citizens of the two cities rather than to the spraying of cadmium.

Appendix 13: Genetics and susceptibility to lead toxicity

Changes in a number of genes and the proteins they produce have been associated with changes in blood lead levels or in lead toxicity. This is a promising area for further research and may help explain why there are reports of individuals who experience more toxicity to lead compared to other individuals who have similar environmental lead exposures.

Evidence suggests that changes in the following genes may influence lead accumulation and/or distribution the in body (Analaja and Claudio 2000; Whitfield et al. 2007):

1) The gene coding for delta-aminolevulinic acid dehydrotase (ALAD) a protein present in red blood cells which is important for heme synthesis. Lead is known to bind tightly to ALAD and to inhibit heme synthesis as a result.
2) The gene coding for the vitamin D receptor gene (VDR). The vitamin D receptor plays an important role in influencing calcium transport from the intestine into the body. Lead is known to compete with calcium in being transported from the intestine into the body.
3) The gene coding for the HFE protein. Abnormalities in this protein can lead to a condition called hemochromatosis in which iron is accumulated in the body. It has been speculated that there is a relationship between the body's handling of iron and its handling of lead.
4) The gene SLC 4A7 coding for a bicarbonate transporter protein. There is evidence that the movement of lead into red blood cells depends in part on bicarbonate transport.

Evidence suggests that changes in the following genes or proteins may impact the toxicity of lead on the brain.

1) The enzyme (a protein) arylsulfatase A (ASA). There is evidence to suggest that ASA, a protein important to brain function is a target of lead action in the central nervous system, and could explain the action of lead to cause learning and behavioural disabilities (Taylor et al. 2016).
2) The GRIN2A and GRIN2B genes. There is evidence that the toxicity of lead on the cells of the central nervous system may be modulated by changes in these genes which encode proteins which are important for brain function, in particular for learning, memory and executive function (Rooney et al 2018).

While the results of these studies are not conclusive for all these inferences, they show that there is the potential for major advances in the understanding, and thus potentially in the prevention and/or treatment of children and adults with respect to the effects of lead toxicity.

Appendix 14: Chelation Therapy and the therapy for youth and adults

While the treatment approach for very young children with high lead levels – up to age three, is now well established thanks to the work of Billings and Schnepel (2018), a few comments on chelation therapy and on therapy for youth and adults are needed.

Chelation Therapy: Chelation therapy uses a drug which binds to lead and removes the lead. There is general agreement on the use of chelation therapy where lead levels are very high (45 ug/dL or higher) (Mayo Clinic 2020).

A careful randomized controlled trial was conducted for children up to three years of age (Rogan et al. 2001; McKay 2013) with two blood lead levels between 20 and 44 ug/dL who were living in Philadelphia, Newark, Cincinnati and Baltimore. This study showed no difference in IQ, behaviour or psychological assessment results 36 months after the start of treatment or at age 7 between the treatment and the control group. There are several point which are worth commenting on.

1) The group who received the chelation treatment showed a rapid drop in their lead level initially but by 36 months when the testing was done there was no significant difference between the lead levels of the two groups as the children in the group which received the placebo showed a decline in lead levels comparable to that of the group receiving chelation. This is undoubtedly because both groups were provided measures to reduce lead exposure. McKay (2013) concluded "Clinically, the reasonable inference is that the way to prevent lead-associated defects is to prevent lead exposure."
2) Both those who received chelation and the control group received a careful housecleaning (the area where these children lived had many houses with "deteriorated lead-based paint"). The authors comment "Children ingested lead by playing with and eating the big flakes of paint, as well as the dust from it on their fingers, stuffed animals, and anything else they may put in their mouths." Following an inspection of the home, "The next step was to clean the houses. … Cleaning crews in hazmat suits would gather up all the dust. In particular, we found that the area behind radiators, which habitually were under windows, were a great source of dust." As well all families were given "public health service brand multivitamins for the child."
3) These efforts at lead remediation can be compared to that described by Billings and Schnepel (2013) in Charlotte-Mecklenburg County in North Carolina. In North Carolina "The provision of lead remediation services involves the removal of lead contaminants, which usually requires the replacement of windows and doors and the repainting of interior/exterior walls. During our sample time period, lead remediation was primarily funded through local government agencies, HUD-based lead remediation grants, nonprofits, and privately. The cost of lead remediation is not trivial with the average price for these repairs totally $7,291." The fact that the intervention was less robust in the study of Rogan (2001) and McKay (2013) than the intervention in Charlotte-Mecklenburg County is consistent with the finding of McKay that a number of children in their study had "abrupt increases in BLL," with 17 of the children (seven in

the placebo arm and 10 in the chelation arm) having rises above 44 ug/dL. The Charlotte-Mecklenburg County study also used a greater intervention with respect to nutrition and with respect of psychosocial interventions. Thus the lack of overall improvement in IQ, behaviour or on psychometric assessment does not rule out that the more intensive intervention used in Charlotte-Mecklenberg County might have had a greater effect. In fact the Charlotte-Mecklenberg County results reported "a marginally significant" increase in educational performance, but "a large and significant decline in anti-social behaviour associated with elevated BLL intervention." The better results in the Charlotte-Mecklenburg County study may also reflect the fact that many of the children who received the intervention in their study had lower blood lead levels (10 ug/dL and up) as opposed to 20 - 44 ug/dL in the Rogan/MacKay study. Overall these results support the fact that partial interventions are not sufficient (see also Markowitz and Rosner 2013).

Therapy for Youth and Adults:

For very high blood lead levels (45 ug/dL and above) and for acute lead toxicity, chelation therapy may be considered (see above).

There has been a tendency in the past to accept higher blood levels in adults. However, the evidence as discussed earlier, suggests that lower levels of lead may be associated with mental illnesses and dementia in adults. Lead has also been implicated in the development of age-related macular degeneration (Erie et al. 2009). Further in the recent UNICEF-Pure Earth report (Rees and Fuller 2020), it is recognized that lead exposure accounts for 8.2% of the global burden of hypertensive heart disease, 4.6 percent of the global burden of ischemic heart disease, 4.7 percent of the global burden of stroke and 2.9 percent of the global burden of chronic kidney disease. The Textbook, *The Medical Basis of Psychiatry*, lists the normal range for blood lead in adults as less than 10 ug/dL (Fatemi and Clayton 2016). With the discussion in this report and elsewhere of the use of less than 5 ug/dL for children it may be asked whether the adult range should also be reduced. Nevertheless, accepting the normal range for adults as less than 10 ug/dL, this suggests that any individual with a blood lead level above this should be coached on measures to take to reduce lead exposure, should be coached on dietary and nutrition measures to reduce lead absorption, and should be evaluated with respect to the presence of a learning disability, hypertension, mental illnesses, substance abuse and risk factors for heart disease, stroke and dementia. Blood lead levels should be followed to ensure that the level is falling, following these measures. As with the treatment of children, it will be important to address not just the lead levels, but also the broader health impact of the high blood lead level including the psycho-social impacts.

There may also be, given the connection between blood lead levels and crime, a potentially important role of physicians to investigate the blood lead levels in individuals accused and/or convicted of crimes. Where they are found to have high blood lead levels, the same measures will need to be taken to 1) decrease future exposure to lead, 2) address dietary and nutritional aspects to reduce lead absorption (see section on nutrition), 3) address associated physical and mental health conditions including in

particular assessing heart and kidney disease as well as mental health, substance abuse and risk of dementia.

The issue of substance abuse in relationship to blood lead levels warrants further discussion. There is a clear increase in alcohol consumption associated with an increase in red blood cell lead levels (Figure 36).

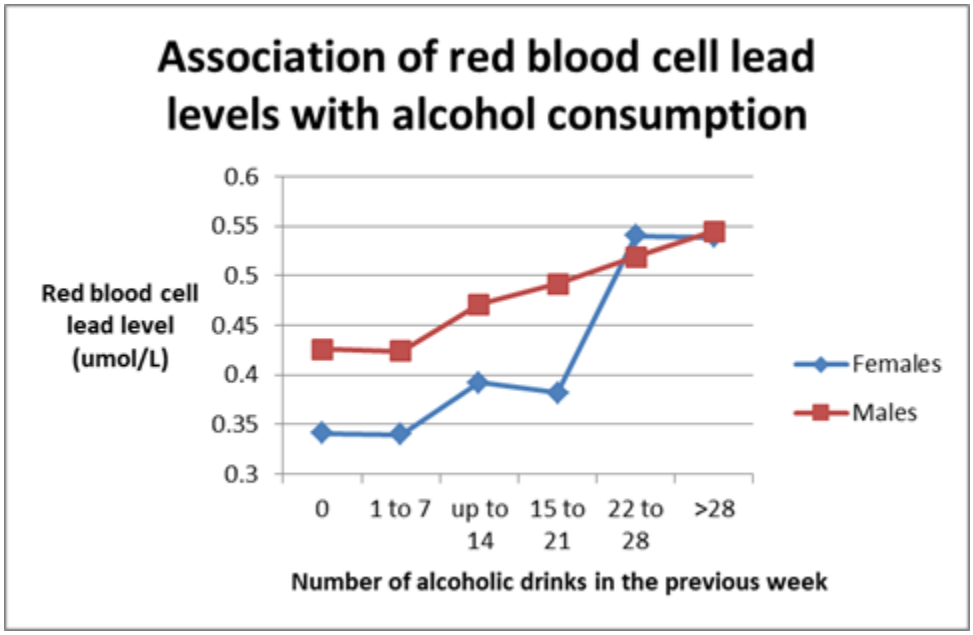

Figure 36: A comparison of red blood cell (erythrocyte) lead levels and alcohol consumption. In this study red blood cell lead levels were measured instead of whole blood lead. Approximately 99% of lead in blood is in red blood cells. For comparison 5 ug/ml in whole blood equals 0.24 umol/L in whole blood which equals approximately 0.40 umol/L in red blood cells. Data are from Whitfield et al 2007.

The high blood lead level could be a result of the alcohol consumption or the increased alcohol consumption could be a result of the high blood lead level. In fact, as described earlier in this report, there is substantial evidence that a high blood level leads to changes in the brain which result in increased ethanol consumption and increased addiction. At the same time, there is evidence that ethanol consumption can result in increased lead levels in the blood and the brain. The results may be a vicious cycle in which lead exposure promotes ethanol consumption and addiction and the resulting ethanol consumption induces biochemical changes which lead to further lead accumulation (see page 12). Based on the evidence to date individuals with substance abuse issues who have high lead levels may benefit from the high lead levels and the addiction being treated at the same time

To add to the above, as Taylor R (202) indicates “There is significant data that indicates that alcohol may also increase the susceptibility of some organs, to lead toxicity”. Thus there may be more than one reason to address lead exposure and alcohol consumption at the same time.

Appendix 15: Addressing the evidence against the concept that lead exposure leads to crime.

In a report, based on scientific evidence, as this one is, it is important to look at those scientific reports which have provided contrary evidence.

The paper of Fergusson et al (2007) which found a link between lead and crime but concluded it was weak, has already been discussed (See comments are on pages 47 to 49 and in Appendix 1). Fergusson's studies clearly showed that lead exposure and criminal activity are linked and that part of the pathway from lead to crime is through the impact of lead to decrease school performance. In the report and in Appendix 1 a reanalysis of the data of Fergusson et al has provided evidence that the data in the paper suggest a much larger impact of lead on crime than the original analysis by the authors.

There remain two studies which need to be discussed further:

1) **Beckley et al. 2017**

   This is an analysis of the material gathered in the Dunedin region of New Zealand using blood lead levels measured at age 11. They say in their conclusion that their "findings failed to support a dose-response association between BLL and consequential criminal offending." There are several issues with the study of Beckley et al and their analysis. 1) The study of Beckley measured lead levels at age 11. All the information we have suggests that it is lead levels in fetal life and in the first two years after birth which are most important. This is at a time when the brain is developing and analysis after analysis has shown that the maximum impact of the lead exposure around the time of birth is reflected in the crime rate 20-22 years later. There may have been significant changes in lead levels from birth to eleven years of age as a result of changes in the home or the environment. 2) In doing the analysis the authors had to drop the inclusion of children living in rural areas around Dunedin. The children were born at the high point of lead exposure in leaded gasoline, and other data suggests that lead levels were highest in larger centres where there were a lot more cars being driven and more lead emitted from gasoline. In omitting these children, the authors may have inadvertently omitted children with the lowest lead exposures, a group which would have been very critical to their analysis. Compared to the study of Billings et al (2013), there were far fewer children in the low lead level group (33 in the study of Beckley had blood lead levels of $\leq$ 5 ug/dL and 1941 children in the study of Billings and Schnepel had their initial blood lead level between 1 and 5 ug/dL). Further, the lowest blood level measured in the whole group studied by Beckley was 4 ug/dL. This is important as the data from Billings and Schnepel show that levels of 3 ug/ml and above are associated with significant criminal activity. Overall, the data of Billings and Schnepel is much more robust. As a result, the work of Fergusson (2007) and the work of Billings and Schnepel is to be trusted much more than the results of Beckley. 3) It is also noteworthy that the group as a whole had a high level of criminal convictions (27.8% average for the whole group). There was an increase in criminal convictions from 23.0 % in those with blood lead levels from 6-10 ug/dLl to 35.3% for those with blood lead levels from 11-15 ug/dL (these were the two groups

with the largest number of children) but the overall trend across all blood lead levels was not statistically significant.

2) Sampson and Winter 2018:

These authors provide compelling evidence from a study of neighbourhoods in Chicago, that parent reported anti-social behaviour in adolescence is related to blood lead levels taken around three years of age. Children with higher blood lead levels exhibited significantly more anti-social behaviours including destroying things belonging to his/her family or others, displaying cruelty, bullying or meanness to others, being disobedient at school, not feeling guilty about misbehaving and lying or cheating. They comment that their findings "demonstrates a significant relationship between childhood lead exposure and anti-social behaviour in both childhood and adolescence after our individual neighbourhood controls are adjusted". They go on to say "The consistency of the relationship between lead exposure and antisocial behaviour over time is indicative of the durable effects of lead exposure over the early life course. It is notable that no control variable that we included exhibited a similarly durable association with antisocial behaviour." Their results in this regard are entirely consistent with a variety of other studies which link antisocial behaviour in adolescence to early childhood lead exposure as documented earlier in the body of the present report.

Sampson and Winter also show that antisocial behaviour "robustly and significantly correlates to arrest." They continue "This finding holds whether we consider arrests for any crime, arrests for property crime, or arrests for nonviolent and non-property crimes."

However, when it came to the relationship between childhood blood lead levels and arrests they found the following: "On average, childhood lead exposure was slightly higher among those in our sample who had been arrested (6.55 ug/dL, SD 3.56) than among those who had never been arrested (6.10 ug/dL, SD 4.87), and even higher among those who had been arrested for a violent crime (7.55 ug/dL, SD 3.82)." However "these differences are a weak signal and not statistically significant – childhood lead exposure on its own does not directly relate to arrests of any type, controlling for our covariates."

It is difficult to explain why there is a very strong link between lead exposure and antisocial behaviour, a strong link between antisocial behavior and crime, but not a significant link between lead exposure and crime. The authors admit "Our sample size is also small, so our power to detect differences was constrained. Future research from other places with larger samples is needed" It is likely that the small sample size may be critical here. It is also not clear how many of the blood lead levels in the small sample size were below 3 ug/ml. As noted above in the study of Beckely, the work of Billings and Schnepel (2018) contains a much larger sample of children with levels between 1 and 5 ug/ml. Further, notwithstanding the results of Sampson and Winter there is now a large body of evidence from multiple studies which links lead exposure to crime as demonstrated in this report and in a thorough analysis of Crime Correlates (Ellis et al 2019). Thus the weight of evidence strongly links lead exposure to crime. The overall results of the study of Sampson and Winter thus support the findings described in this report in relation to the connection between lead and antisocial behaviour, and they support the known association between antisocial behaviour and crime even if, in their small sample, the link between lead

and crime is weak and not significant. The results are thus not sufficient to reject the concept that lead exposure leads to crime, and that as, outlined in Figure 23, the impact of lead on crime is mediated through various pathways.

It is important to note, with both these studies, that the work of Lanphear (2005) suggests that there is a log-linear relationship between changes in children's IQ and blood lead level (Figure 37). To illustrate further, Lanphear found that as blood lead levels increased from less than I to 10 ug/dL, there was a decline of 6.2 IQ points. To compare, as the blood lead levels increased from 10 to 20 ug/dl, the decline in IQ was only 1.9 points, and from 20 to 30 ug/dL the decline in IQ was only 1.1 points. This graph emphasizes how important it is to have assessed significant numbers of children with very low lead levels in order to see the full impact of the increased blood lead levels. The lack of sufficient number of children with very low blood lead levels appears to have been a significant problem with both the work of Beckley and of Sampson.

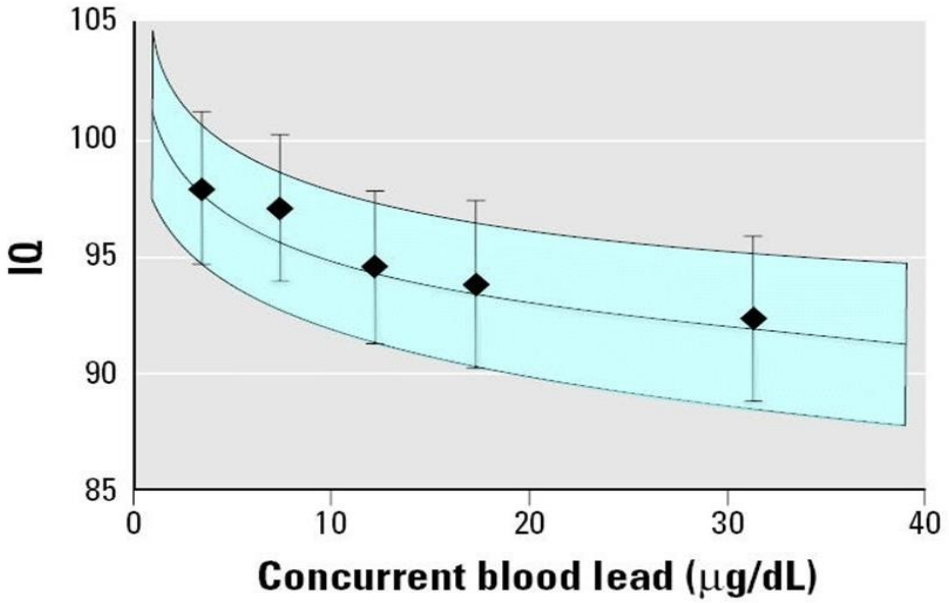

Figure 37: The relationship between blood lead levels best fits a log linear model as shown in this Figure. The shaded area is the 95% confidence interval for the range from the data. The data were adjusted for HOME score, for maternal education, for maternal IQ and for birth weight. The mean IQ (with 95% confidence interval) are shown for < 5ug/dL, for 5-10 ug/dL, for 10-15 ug/dL, for 15-20 ug/dL and for > 20ug/dL. Data are from Lanphear et al 2005.

The CDC in the United States: It should be added that the CDC (2020c) in its information acknowledges the association between lead and criminality saying: "Lead exposure can affect nearly every system in the body and is associated with numerous behavioral and learning problems (e.g. reduced IQ, attention-deficit/ hyperactivity disorder, juvenile delinquency, and criminal behavior)." Those who argue against

the fact that lead exposure can lead to criminal activity and crime need to provide better evidence than these studies if they want to continue to advocate this position.

Appendix 16: The case for universal screening of children for blood lead levels

In New York State all health care providers are required by law and regulations to test all children for their blood lead level at one year of age and again at age two. In addition all health care providers must use standardized questionnaires to assess all children ages 6 months to 6 years at every routine visit for lead exposure potential (New York State Department of Health 2019. In Michigan, all children residing in postal codes with a history of high blood lead levels are required to be tested (CLPPCC 2007). In addition, all children covered by Medicaid must be tested for lead exposure at ages 1 or 2 years or 3 to 5 years of age (Gomez et al 2019). Maine also requires all children eligible for Medicaid to have a blood lead test between the ages of 1 and 2 years. Alaska recommends and provides for universal testing of all Medicaid-eligible children.

We are at a point in Manitoba where we need to consider universal blood lead testing for children age 1-3 years of age. A universal program is better for several reasons. It does not discriminate. Children and families move from one area to another so mandating testing by postal code of address is not sufficient. Manitoba needs to address this issue well as it is not been adequately addressed to date. When we have better information on the distribution of high lead levels and the reasons for these we can be more focused in our testing.

In addition to testing, the requirement for health care providers to carry out a standardized lead risk screen at each visit from age 1 to 4 is reasonable.

Appendix 17: Possible changes to strengthen provincial and federal environmental legislation

Recognizing the seriousness of lead pollution in its effects of human and societal potential, it is important to have a review of provincial and federal legislation to ensure that lead pollution is adequately assessed during any licensing processes and that there is adequate enforcement in relation to lead. These should include looking at the following:

1. Provincial and Federal Regulatory standards
    a. Are the standards high enough? Do they adequately protect Manitobans from unnecessary exposure to unsafe lead levels?
    b. Are the standards scientifically supported, evidence based with decisions free of political influence.
    c. How can enforcement measures be strengthened?
    d. How can The Federal, Provincial and Municipal governments work together better to support licensing, enforcement, and inspections of industrial operations?
    e. Can the grandfathering of existing industries from environmental lead standards be eliminated, so that existing companies cannot bypass environmental protection?
    f. Should there be required air monitoring stations in "hot spot" areas, in particular in industrial areas which include scrap metal and battery recycling industries?
2. Is there adequate legislation to ensure that industrial company owners maintain appropriate cleanup insurance including a security deposit that is proportional to the risk level for use as payment toward remediation from potential environmental damage and to address potential health liabilities?
3. Should there be a "right to repair law" that would reduce unnecessary waste and keep lead and other materials out of landfills?
4. Should there be required air monitoring stations in "hot spot" areas, in particular in industrial areas which include scrap metal and battery recycling industries?
5. Are there adequate disaster management practices to include such items as?
    a. Dangerous goods routes in all municipalities, whether by roadway, rail, water, or air
    b. Guidelines for prevention of conflicting land uses ie. rail, residential, high-risk industry

Appendix 18: A message to those with high blood lead levels and their families

I write this, to bring attention to you and/or your family when you, or a family member, have been found to have a high lead level.

Finding you have a high lead level in your blood is not a disaster. Knowledge is power. This can open the door to understanding things which are or are not happening in your life. Once this door is opened, it means that you have the ability to look at your life in a new way and to address this high lead level and at the same time to address any concerns it may be causing. This approach has been helpful in many other medical conditions including as examples Fetal Alcohol Spectrum Disorders, Autism, and we need to do this also with lead toxicity.

You may read or be told that the effects of lead on the brain are permanent and cannot be reversed. While there may be some evidence which suggests that some aspects of the impact of lead on a person's brain may be difficult to reverse, in my review of these studies, the evidence is not unequivocal or conclusive.[1] Indeed, not long ago, we thought it was difficult to change the brain. Now we know a lot about brain plasticity – that many things we thought were unchangeable in the brain, we now know can be changed.

Knowing that a person has been exposed to lead can help address the situation. For example, one of the common effects of lead on a person's brain is difficulty in learning. Such difficulty in learning can be helped by extra coaching and help. Further, the means for helping individuals who have learning disabilities are steadily improving. In addition, it may turn out that the changes due to lead may be similar in many children who have been exposed to lead. If that is the case, there may be specific types of help which are most useful to a person whose brain has been affected by lead. As an example, Helen Irlen (2005) has found that a proportion of people with difficulty reading have a condition which she calls Scotopic Sensitivity Syndrome. Children with this condition have difficulty reading black letters on a white background, but can read well when they use a coloured filter. If many individuals with lead affected brains have this type of reading difficulty, this can be a helpful approach. If individuals with lead affected brains never have this type of reading difficulty, then this narrows down the reason for the learning difficulty, and will enable a focus on other approaches.

We have learned much from helping children deal with other conditions where there are learning difficulties. For example, children with a Fetal Alcohol Spectrum Disorder (FASD), whose brains are affected by exposure to alcohol during fetal life have been found to be more likely to engage in criminal activity when they grow up. However, we now know that identifying such children and helping them early in life is protective in the sense that they do much better and are much less likely to engage in criminal activities. Why is this? Too often children with FASD are not identified early on, and are labelled as "bad, terrible, no-good children". When a child is labelled like this and blamed for the problems he or she causes, it can lead to bad results for the child. When a child is identified as having FASD, then there is an explanation for his or her behaviour and parents and caregivers tend to be more

understanding, empathetic and helpful and so the child grows up and often does very well. So it can be with a child with a lead affected brain, who may be hyperactive, impulsive and difficult to handle. When we can identify a reason for the behaviour, we can better develop a plan to reduce the lead exposure and to help the child.

When we can do better at screening children early on, and better at addressing the lead affected brain we can achieve better results. A careful study, described in detail in this report done by Stephen Billings and Kevin Schnepel (2018), shows that when identified within the first three years of life, children can be helped and at least some of the negative consequences of a lead affected brain can be avoided. As these two scientists showed, doing remediation to reduce or eliminate further lead exposure, addressing nutrition to decrease the likelihood of lead absorption, and vigorously addressing learning or behavioural difficulties can lead to results in which these children are no longer "problem" children, but are children who can do very well.

We are not yet, in Manitoba, or in Canada, at a point where we are doing adequate screening of children early on, nor are we yet at a point where every child identified with a high lead level is receiving the supports needed for the child to do well. I hope you will work with me to influence health professionals and politicians to achieve these improvements so that every child with a lead affected brain can do well, and so that in the future we will have many fewer children born with lead affected brains.

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1 – For example, in one study which did not show reversal of the effects of lead using chelators to remove lead (Rogan et al 2001), aspects of the mitigation and treatment approach used was less rigorous than that used in the study of Billings and Schnepel (2018) which did show that a larger effort to remove lead exposure and a more vigorous treatment approach was successful in preventing major behavioural problems including criminality.