



National Carbon Monoxide  
Awareness Association



## ***CARBON MONOXIDE POISONING IN VULNERABLE POPULATIONS, PART I:***

# **CHILDREN, INFANTS, AND UNBORN BABIES**

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## AUTHORS

### **Brianna J. Sleezer, PhD**

#### *Science and Medical Writer*

Brianna holds her doctorate degree in Neuroscience from the University of Rochester School of Medicine and Dentistry. After completing her graduate work, she worked as a postdoctoral researcher at Cornell University where she studied the brain circuits regulating cognition and emotion. During her time as a neuroscientist, Brianna wrote and published numerous research papers and presented her findings at conferences across the country.

Brianna now works as a science and medical writer specializing in biomedical communications within the pharmaceutical, healthcare, and biotechnology industries. Brianna provides NCOAA with a biomedical perspective and offers strategic direction for achieving the organization's goals for better screening and early detection.

### **Charon McNabb**

#### *President and Founder*

Charon holds a bachelor's degree in Electrical Engineering from Lawrence Technological University. She spent 25 years in the automotive industry focused on new technology development with General Motors, Denso, and Magna International. She also worked with National Highway Traffic Safety Association (NHTSA) to drive new backup camera regulations beginning in 2018. Her engineering background and experience working with the NHTSA provide insight essential to achieving the goal of improved legislation and standards for carbon monoxide poisoning detection and prevention.

### **Dennis O'Meara, PMP**

#### *Director of Operations*

Dennis holds a bachelor's degree in Business Administration from Concordia University. He has 40 years of experience in design, product engineering, and program management within the automotive market. Dennis has lived and worked abroad, supporting new European product launches. He also holds his PMP certification. His strong organization and communication skills have been a solid asset to NCOAA since joining the organization in 2019.

### **Nikki James Zellner**

#### *Director of Community Outreach*

In February 2020, Nikki's life changed forever when her two young children suffered carbon monoxide poisoning at their Virginia Beach daycare. Since then, she has made headlines as an advocate and activist in the State of Virginia, in pursuit of legislation mandating carbon monoxide detectors in all educational facilities. Nikki focuses her efforts on making a significant impact in the communities she is a part of – including carbon monoxide poisoning prevention, military spouse entrepreneurship, finding success despite chronic illness, and breaking the cycle of poverty by sharing the power of entrepreneurship to underserved communities.

## INTRODUCTION

Carbon monoxide (CO) is a toxic, colorless, odorless, and tasteless gas produced by burning materials like wood, charcoal, gasoline, and natural gas. CO is a primary cause of unintentional poisoning in the US, and, at high levels, can lead to death within minutes<sup>1,2</sup>. All homes and buildings with fuel-burning appliances and/or attached garages pose a risk for CO poisoning and proper precautions must be taken to prevent CO exposure.

The exact symptoms of CO poisoning can vary widely and depend on the concentration and duration of CO exposure and each individual's preexisting health status. Mild CO poisoning symptoms typically include fatigue, headaches, dizziness, and nausea, while severe symptoms include cardiorespiratory failure, seizures, unconsciousness, coma, and death<sup>1,3</sup>. CO exposure has also been linked to a number of long-term adverse health effects, including heart disease, stroke, cognitive and memory impairments, sensory-motor deficits, emotional changes, congenital defects, and low birth weight<sup>4-14</sup>.

**CO exposure is especially harmful to developing bodies.**

### CO REDUCES THE BODY'S ABILITY TO CARRY OXYGEN TO VITAL ORGANS

When CO is inhaled, it binds to hemoglobin, a protein in red blood cells which normally transports oxygen from the lungs to the rest of the body. When CO binds to hemoglobin, it displaces oxygen to form a complex known as carboxyhemoglobin (COHb), which impairs oxygen transport throughout the body<sup>15</sup>. Without sufficient oxygen, the body's cells will begin to die and vital organs will stop functioning. Some organs in the body (namely, the heart and brain) require more oxygen than others, and, as a result, are more prone to damage from CO than other organs.

Since oxygen is essential for the normal development of vital organs, CO exposure in developing bodies (i.e., children, infants, and unborn babies) is particularly harmful and can lead to long-term developmental abnormalities<sup>16</sup>.



### CHILDREN, INFANTS, AND UNBORN BABIES ARE PARTICULARLY SUSCEPTIBLE TO CO POISONING

While everyone is at risk for CO poisoning, children, infants, and unborn babies may be more susceptible to CO poisoning for the following reasons:

#### **Children, infants, and unborn babies have faster metabolisms and smaller body sizes**

Higher metabolic rates (including faster heart rates and faster breathing rates) and smaller bodies have two important implications for CO exposure. First, because children and infants breathe faster than adults, they breathe in more CO, making it more likely that they will be poisoned by CO than adults. Second, a faster metabolism means that children's bodies eliminate CO more quickly once they are removed from the source of CO<sup>17</sup>. This makes it difficult to determine a child's level of CO exposure at a hospital or doctor's office because much of the CO in their body will already be gone by the time they are examined by a doctor. The rapid elimination of CO from children's bodies makes it difficult to properly diagnose CO poisoning.

### Children and infants may have difficulty vocalizing and/or recognizing symptoms

Children and infants typically have more difficulty than adults recognizing CO poisoning symptoms and may not tell an adult that they are not feeling well. Given that symptoms of CO poisoning in adults often occur at higher levels of CO compared to children, CO poisoning in children may go undetected at lower levels of CO.

### Fetal hemoglobin has a greater binding affinity for CO than adult hemoglobin

When pregnant women are exposed to CO, CO can cross the placenta and enter into fetal blood circulation<sup>18</sup>. Fetal hemoglobin has a greater binding affinity for CO than adult hemoglobin<sup>19</sup>, meaning that CO can greatly impair oxygen transport throughout fetal tissues. CO poisoning in pregnant women can cause premature birth, birth defects, fetal death, and fetal brain damage<sup>16, 19-22</sup>.



### CO EXPOSURE IN PREGNANT WOMEN CAN IMPAIR FETAL DEVELOPMENT

The impact of CO exposure on pregnant women is incompletely understood, partly because reports of CO exposure in pregnant women are rare. Given that some of the symptoms of CO exposure are similar to those that many women experience during pregnancy (e.g., nausea and fatigue), it is

possible that CO exposure in pregnant women is underrecognized and, therefore, underreported. Nevertheless, the available evidence does suggest a possible link between CO exposure in pregnant women and poor birth outcomes. For example, some studies have found a link between exposure to higher levels of CO in air pollution during the first trimester and increased risk of miscarriage, and a link between exposure to higher levels of CO in air pollution during the third trimester and increased risk of stillbirth<sup>22</sup>. In the case of high-level acute CO exposure, fetal birth defects and/or death are more common among pregnant women who experience a loss of consciousness as a result of CO exposure compared to women who are exposed to CO but do not experience a loss of consciousness<sup>20</sup>.

### CO EXPOSURE DISRUPTS BRAIN DEVELOPMENT IN CHILDREN, INFANTS, AND UNBORN BABIES

One organ that is particularly susceptible to damage from CO exposure is the brain. While the brain's basic structure is set up by the time a baby is born, the brain continues to develop and change long after birth, and these changes are critical to normal adult brain function. CO poisoning can disrupt a number of neurodevelopmental processes, including: brain cell proliferation and migration<sup>23</sup>, neurotransmitter level<sup>24</sup>, production of myelin (a fat-like substance that plays a critical role in normal conduction of electrical impulses along nerve cells)<sup>25</sup>, developmental neuroapoptosis (a critical part of brain development in which excess and inappropriately integrated brain cells are destroyed)<sup>26</sup>, and development of the blood brain barrier (a network of blood vessels and tissue that helps protect the brain against pathogens and toxins).

By disrupting critical neurodevelopmental processes, CO exposure can lead to long-term abnormalities in cognition and behavior, including memory impairment and abnormal social behavior<sup>26</sup>. CO poisoning in children can also cause a phenomenon known as delayed neurologic sequelae (DNS). DNS is the sudden appearance of severe neuropsychological issues after a period of recovery from initial CO symptoms. DNS typically appears between 27 to 270 days following initial CO exposure and can also occur in adults<sup>27,28</sup>.

## CO ALARMS ARE CRITICAL TO PREVENT CO POISONING IN CHILDREN, INFANTS, AND UNBORN BABIES

Because CO is imperceptible to human senses, CO alarms are an important tool to prevent CO exposure. However, some states do not require CO alarms in schools or daycares. Moreover, many schools and daycares do not require staff and/or educators to be trained in CO safety or awareness. Only 6 states (New

Jersey, New York, Ohio, Utah, Vermont, and Virginia) currently have state-wide legislation requiring CO alarms in existing schools<sup>29,30</sup>, leaving both children and educators at risk of CO poisoning. Although legislation requiring CO alarms in existing daycares is more widely adopted across the US - with 35 states requiring CO alarms in existing daycares<sup>29</sup> - much work still needs to be done in improving both legislation and education/awareness of CO poisoning in schools and daycares across the US.

### ONE CHILD FOUND DEAD, AND MULTIPLE UNCONSCIOUS FOLLOWING CO LEAK AT MICHIGAN POOL

In 2017, a group of children, ages 12 to 14, attended a birthday pool party at a Quality Inn and Suites in Niles, Michigan. At some point during the party, a hotel staff member walked by the pool area and noticed 6 children laying unresponsive and unconscious on the pool deck. Although the hotel staff were quick to open the doors and call 911, it was too late to save all the children. Tragically, 13 year old Bryan Watts died en route to the hospital.



Perhaps the most tragic part of this story is the fact that it could have been prevented. The CO leak, which was due to a broken pool heater, led to the accumulation of very high levels of CO within the pool area. According to first responders, CO levels in the pool area were 800 parts per million (ppm). CO alarms are required to sound when CO levels reach 70 ppm. Unfortunately, the hotel pool area did not have a CO alarm - if it had, it likely would have signaled danger before tragedy struck.

## AFTER HER CHILDREN WERE POISONED, ONE MOTHER WORKS TIRELESSLY TO CHANGE CO LEGISLATION FOR DAYCARES AND SCHOOLS

On February 20, 2020, Nikki James Zellner received an emergency notification from Kids Town Learning Center, the daycare where her two sons - Ronan and Owen - attended in Virginia Beach. The notification informed parents of a gas leak and urged them to come pick up their children. When Zellner arrived at the daycare, she found the street lined with emergency vehicles and discovered that the children and staff had been evacuated. As she frantically tried to figure out what had happened, she started to grow more and more concerned.

"I was starting to hear stories related to what was going on behind the scenes," Zellner said. "The one that gave me the biggest pause was that a teacher's boyfriend had to bring in a detector because the teachers and students were getting sick after hours of symptoms, and there was no detector on site."

In that moment, Zellner decided that something needed to be done to prevent an event like this from happening again. After researching Virginia CO alarm legislation, Zellner discovered that although CO alarms were mandatory in new buildings (including daycares), this requirement didn't apply to buildings constructed before 2015. But there was a catch: Virginia building codes could only be changed through legislation; and, from that point forward, Zellner began advocating for safer schools in Virginia through legislative change.

Zellner's first action was to create a Change.org petition to require CO detectors in Virginia schools and daycares. Zellner's efforts paid off - a week after she started the petition, she was interviewed for a front page news article that appeared in both the Virginian-Pilot and the Daily Press, two of Virginia's leading newspapers, and received a commitment from a legislator to work with Zellner to introduce new CO legislation in 2021.

On February 22, 2021, exactly one year after Zellner's children were poisoned by CO - Virginia legislators approved HB1823, requiring CO alarms in daycares and schools built before 2015. The law went into effect July 1, 2021.



# WAYS TO SUPPORT CO AWARENESS

NCOAA is a 501(c)(3) nonprofit dedicated to CO awareness and safety. Our mission is to initiate a global conversation on the diagnoses, treatment, and prevention of chronic and acute carbon monoxide poisoning by organizing available CO poisoning information and driving change to improve diagnostics, detection, treatment, legislation, and standards throughout the globe. You can help prevent senseless CO injuries and deaths by making a gift to NCOAA.

Supporting NCOAA is easy!

1. Visit our website at [www.ncoaa.us/donations](http://www.ncoaa.us/donations) or scan the QR code below to make a secure online donation:



2. Mail your contribution to NCOAA at:  
6855 Oakhills Drive  
Bloomfield Hills, MI 48301

To make a donation by phone or to arrange an in-kind donation in support of our mission, contact us at [info@ncoaa.us](mailto:info@ncoaa.us).

Connect with us on social media and join the conversation:



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