Toxic Metals and Corrosive Pipes in the United States Water Distribution Systems

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Abstract

Water distribution pipes throughout the United States are susceptible to corrosion, which can lead to detrimental downstream effects. Pipe corrosion leads to the release of toxic metals into the water supply, posing significant health hazards to individuals who consume or come into contact with treated tap water. This study aims to examine the cause of toxic metals, specifically lead, copper, iron, and cadmium, in the drinking water resulting from pipe corrosion in the United States. In addition, this paper aims to identify the various health risks associated with the ingestion of these toxic metals.

Introduction

Water is an abundant resource around the world. However, in many countries around the world, including the United States, individuals have experienced health concerns due to the lack of clean drinking water. As technology continues to advance, so does wastewater treatment infrastructure. Despite the improvements made to wastewater technology to sanitize water, waterborne disease outbreaks continue to occur in the United States. These diseases have been heavily linked to the deterioration of wastewater infrastructure as well as water distribution systems. Aging wastewater infrastructure has been one of the root causes of contaminated water in the United States. The American Society of Civil Engineers' 2021 Infrastructure Report Card gave the United States water and wastewater systems a D+ for quality [18]. The number one concern of water utility workers in North America is renewing the country's aging water and wastewater infrastructure [6].

Background

Wastewater treatment is a process where wastewater gets treated to change its quality for drinking and sanitary purposes. The treatment process takes place in wastewater treatment plants. Types of wastewater include sewage, stormwater runoff, and contaminated rainwater. Water from all of these sources is then treated and released back into the environment. Initially, sewage is generated from multiple sources from a mixture of toilet water, washing water, ice, institutions, streets, and rainwater [7]. The treatment process involves different treatment units. Treated water is then transported to homes, businesses, and other water consumers via water systems.

The network of water distribution systems includes larger transmission pipes as well as smaller pipes that deliver water to communities and residential homes. Pipes comprise the largest

portion of wastewater in a drinking water distribution system. Different pipe materials used in the wastewater treatment process are selected based on a combination of trench conditions, corrosion, temperature, safety requirements, and cost [16].

The ASCE reported that United States water utilities experience approximately 250,000-300,000 main breaks of their wastewater infrastructure distribution systems per year. Wastewater infrastructure failures can bring about a wide range of microbial, chemical, and radiological contamination to the drinking water [9]. They can cause health issues when ingested, inhaled, or when in contact with skin. Contaminants and pathogens enter the water that flows through wastewater infrastructure from intrusion, corrosion, and biofilms [9].

Root Cause of Corrosion

Corrosion refers to the gradual deterioration or destruction of the materials used in wastewater treatment plants, such as pipes, resulting from a chemical reaction or a reaction with its surroundings. Corrosion is caused by external elements such as humidity, temperature, and corrosive gasses and is intensified by microbes [3]. Signs of water that have gone through a corrosive infrastructure are the change in the taste and color of the water [8]. The corrosion of pipes and other parts of the water system components degrades the entire wastewater system and necessitates repairs. It is estimated that the US industries spend over 276 billion dollars per year repairing damage from corrosion [6].

Microbes have been shown to have a strong link to the corrosivity in pipes. Microbes inhabit water systems and are potentially pathogenic. Biofilms are microbiologically produced organic polymer matrices that house microbes. Microbial biofilms are harmful when ingested and have the ability to cause physical damage such as corroding pipes [6]. Corrosive water leads to many diseases and poses many health concerns.

Lead

Lead exposure via drinking water consumption has been an issue that has been overlooked in the past decade until reports of contamination were reported. Lead makes its way into the water system through corrosion from metal faucets and fixtures made from brass, which is an alloy composed of zinc and copper that often contains lead impurities [13]. The amount of corrosive lead increases when water's corrosivity increases. In April 2014, a drinking water crisis in Flint, Michigan caught global attention. There have been many reports of lead poisoning and it was identified that there was lead release and lead corrosion [10]. Drinking water from Lake Huron, provided by the Detroit Water and Sewerage Department, to the Flint River was not treated properly, and thus, lead was released and corrosion surfaced exponentially [8]. The concentration of lead in water increased through the lead from leaded pipes as well as an aging

and oversized water distribution system. Lead is regulated by the United States Environmental Protection Agency (EPA) because lead consumption has been known to be linked to health effects that primarily affect pregnant women and young children. Lead consumption can result in behavioral problems, slowed growth, lower IQ, and anemia in young children [15]. The consumption of lead in pregnant women can cause a reduction in the growth of the fetus as well as premature birth. Adults exposed to lead consumption can have serious health issues that include high blood pressure, reproductive problems, as well as a decrease in kidney function [15].

Copper

Copper is a common material used for piping in household water distribution systems around the world [17]. However, copper used in water distribution systems is highly affected by corrosion. The corrosivity of copper pipes leads to the release of copper corrosion byproducts that form in the drinking water. Copper pinholes in plumbing have also been a problem in the United States [17]. Pinholes form in pipes as a result of the corrosion of copper pipes. When high amounts of copper get released, the water typically turns to a hue of blue, which is known as the blue water phenomenon [2].

In 2003 alone, the Washington Suburban Sanitary Commission received 5,200 reported cases of pinhole leaks in Maryland [17]. From 1998 to 2004, each of the fifty states in the United States experienced between 1 and 20 reports of pinhole leaks. Maryland, Ohio, Florida, and California are the states that have received the most reports of pinhole leaks. The release of copper in water pipes results from various chemical processes that include electron transfer reactions, copper speciation reactions, and mass transfer processes.

The ingestion of copper can lead to acute and chronic effects. High doses of copper can cause health symptoms in the gastrointestinal tract as well as liver damage [1]. These health symptoms include nausea, cramping, and vomiting.

Iron

Cast iron pipes have been used worldwide to distribute water for over five centuries. Colored water is widely associated with the iron release of corroded pipes. The release of iron pipes is in the either soluble or particulate form [11]. Water quality parameters play a key role in the level of iron release from corroded pipes. Dissolved oxygen, pH levels, alkalinity, buffer intensity, water flow characteristics, temperature, water treatment practices, application of an inhibitor, and fluctuations in water quality all have an effect on the release of iron within the pipes [11]. Oxygen concentration also impacts the corrosion of iron because as the amount of dissolved oxygen increases, the corrosion rate also increases.

The consumption of iron from drinking water can lead to non-carcinogenic health risks. While a small amount of iron ingestion can provide nutritional benefits, excessive iron consumption is an issue because it is linked to chronic diseases that include heart disease and diabetes [4].

Cadmium

Cadmium is an element that poses a significant risk to the health of humans and animals upon ingestion. This element is commonly seen as a water pollutant. It makes its way into the water pipes through leaching and corrosion. The two main water quality factors that play a role in cadmium corrosion are pH and alkalinity.

Cadmium ingestion poses a significant health risk in humans. Once entered into the bloodstream, cadmium attaches to alpha-2-macroglobulin, a plasma protein responsible for ion transport, and albumin, a protein produced by the liver and gets distributed to the liver and kidney [12]. Cadmium concentrates in the pancreas, spleen, heart, and lungs [5]. Individuals who experience cadmium poisoning experience gastrointestinal tract failure, multiorgan system failure, renal disease, neurologic dysfunction, lung cancer, and even death [14].

Conclusion

Lead, copper, iron, and cadmium are commonly found toxic metals that are present in water systems that result from pipe corrosion. Water that we drink on a daily basis has the potential to be contaminated in ways that can harm our health. Pipe corrosion in the United States is becoming an urgent issue that needs to be solved in order to protect our well-being.

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