Risk Assessment of Styrene

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Historical and Current Use

Styrene, C8H8, is a liquid that goes through a polymerization process to form synthetic plastics and rubber. With pure styrene being a clear liquid, it can voluntarily polymerize into solid, plastic form (Bond, 1989). Styrene was first isolated in 1831 from storax. Storax was obtained from the aromatic balsam of the shrub species, *Styrax officinalis.* It was not until the late 1930's that styrene began to make a noticeable appearance in industrial manufacturing facilities.

The use of styrene increased during World War II when the need for rubber tires for vehicles and airplanes. Previously, natural rubbers were being obtained from Asia, however due to natural rubber shortages, the United States began seeking alternative ways to make, or obtain the rubber needed for the tires, with military airplanes requiring one-half ton of rubber and tanks requiring one ton of rubber. By this time the Dow Chemical Company developed a way to isolate styrene in a pure form by the dehydrogenation of ethylbenzene. This new chemical reaction allowed the United States to produce the required amount of synthetic rubber for the duration of World War II (ACS, 1998).

The current use of styrene involves the chemical being produced to make polystyrene, which is used to form light, plastic molds. Styrene can then be copolymerized into other compounds to create other materials such as other types of plastics and rubber to make tires (Britannica, 2020). The versatility of styrene allows it to be produced into multiple different compounds. Styrene is used in packaging, electronics, food containers, insulation, military vehicles, rubber, tires, and auto parts. Consumers of styrene are widely distributed across the world because of the demand for the products in the chemical produces while being cost efficient. With the wide availability of styrene to the general population raises concern for the health and safety because of the potential to cause harm (WHO, 1983). This chemical benefits major manufacturers, contributing to the majority of their profit. One major manufacturer of styrene is Chevron Phillips Chemical Company LLC, contributing to over 2.1 billion pounds of styrene per year (USSEC, 2003).

Historical and Current Regulations

Styrene has been shown to have hazardous effects on the human body, specifically the nervous system, affecting reaction time and sensory nerve function (Gautrin, 1990). Styrene has also been identified to have developmental and carcinogenic effects (Brown, 2000). As a result of these toxic effects of the chemical, regulations and recommended daily exposure have been developed. Regulations of the exposure to styrene were first introduced in 1993 to reduce the exposure of the chemical in products that are in contact with food in the United States (WHO, 1983). Due to the toxic nature of styrene, multiple organizations, locally and globally, have considered implementing regulations against the toxic use of styrene. Organizations such as OSHA and the EPA have identified safe handling and exposure limits for styrene. According to the OSHA, the permissible exposure limit over an 8-hour period is 100 ppm and a permissible instantaneous exposure limit is 600 ppm. The EPA has implemented a restriction on the amount of styrene that enters local waterways to prevent the exposure of the chemical through drinking water. The EPA currently has a 0.1 ppm maximum contaminant level goal (MCLG) regulation on the chemical which is the amount that is safe for drinking water with no adverse effects on the individual exposed. This regulation ensures protections against the possible health outcomes from exposure to styrene (EPA, 2000). Considering the potential toxic effects of these chemicals, regulations preventing the harm to individuals is important to maintain safe workplace exposure and acknowledge the harm it can cause to the general public.

Hazards and Dose-Response Regulations

Banton et al. (2019) conducted studies in different industries to find where the most styrene exposure was and who was most at-risk. They identified the three main industries where workers are exposed to styrene: the FRP (fiber-reinforced polymer) industry, the manufacturing of styrene monomer and polystyrene, and through the production of synthetic rubber (Banton et al., 2019). It was found that the primary route of exposure to styrene in these factory workers is inhalation. They tested roughly 6,000 workers in the styrene monomer/polystyrene industry, 15,000 workers in the SBR industry, and over 100,000 workers in the styrene industry (Banton et al., 2019). It was found that workers in the FRP industry displayed generally high levels of styrene monomer, they ranged from 10-100ppm, and these levels peaked at over 200ppm (Banton et al., 2019). The other two industries, the manufacturing of styrene monomer and polystyrene and the production of synthetic rubber, were both consistently tested with levels below 10ppm. In the FRP industry, it was found that workers developed lung and respiratory cancer at a higher rate than the general population; however, it was strongly suggested that these results were not due to the over-exposure to styrene (Banton et al., 2019).

Rosemond et al. (2010) developed a journal under the Agency for Toxic Substances and Disease Registry. The main purpose of the journal is to provide all people, scientists, doctors, physicians, and the general public, with an understanding of the toxicology of styrene. This journal also used plastic and resin factory workers as their sample and study groups. They tested these groups of people and looked at which method of exposure is most common and it was determined that inhalation was the main route of exposure. The most commonly reported symptom of styrene over-exposure is mucous membrane irritation (Rosemond et al., 2010). All participants in the study experienced nasal irritation after being exposed to 376ppm styrene for one hour (Rosemond et al., 2010). Noticeable changes in the lungs were seen in 4 out of 21 workers who were exposed to styrene for roughly ten years; but exposure levels for these participants were not given (Rosemond et al., 2010). There were no adverse effects observed in styrene workers who were exposed to 50-60ppm styrene for 7 years (Rosemond et al., 2010). The NOAEL seen in this study for styrene sits at 216ppm styrene and the LOAEL sits at 376ppm styrene, and the effect observed was nasal irritation (Rosemond et al., 2010).

Lilijelind et al. (2003) were interested in sampling the same group of people and testing for exposure to styrene both through biological measures and environmental measures because this has seldom been done. The end goal for this journal was to assess and evaluate the exposure-response data and to determine if biological exposure or environmental exposure was more prominent and led to worse toxicity effects. The environmental exposure would lead to ingestion and the environmental exposure would lead to inhalation (Lilijelind et al., 2003). Lilijelind et al. (2003) tested the environmental exposure levels through the breath of the participants, and they tested the biological exposure levels through the urine of the participants. These participants were all employees of styrene reinforced plastic factories (Lilijelind et al., 2003). At the reinforced plastic factories, it was found that the mean styrene exposure among the 12 employee participants was between 4.6 and 66.4 mg/m cubed. It was found that styrene was greater in the participant's breath than in the participant's urine (Lilijelind et al., 2003). It was concluded that the risk of styrene exposure is minimal through the ingestion process and that inhalation exposure poses much more of a threat to plastic factory workers (Lilijelind et al., 2003).

Kogevinas et al. (1994) wrote a peer-reviewed article to determine if styrene exposure puts people at a higher risk for the development of neoplasms, more commonly known as tumors, later in life. This study took place in countries throughout Europe including Italy, Finland, and the United Kingdom. This study consisted of 40,688 workers who were employed by plastic factories where exposure to styrene occurs daily. Styrene exposure was measured through the participants' urine (Kogevinas et al., 1994). On average the styrene levels found in these employees' urine was 205ppm styrene (Kogevinas et al., 1994). After obtaining this initial data, the participants were followed-up with yearly to make note of their health for long-term exposure effects. The researchers found that there were no signs of higher rates of mortality due to neoplasms; however, it is worth noting that neoplasms of the hematopoietic and lymphatic tissues increased after initial exposure to styrene (Kogevinas et al., 1994). Results were open-ended and there was no solid "yes" or "no" to whether styrene increases the risk of developing neoplasms. The conclusion reached was that there is a possibility of higher risk of neoplasms of the hematopoietic and lymphatic tissues among workers in styrene factories (Kogevinas et al., 1994).

Target Populations

Styrene is a widely used chemical; therefore, it has a wide variety of target populations. The individuals at the highest risk for styrene exposure are those who smoke cigarettes due to the inhalation of tobacco smoke that contains large amounts of styrene (Cao et al., 2018). Also at high risk are polymer composites industries and FRP composite workers due to working to open mold operation environments without using proper respiratory protection (Banton et al., 2019). Banton et al. (2019) also stated that these workers are the only styrene producers and manufacturers that have an excess risk for harmful effects of styrene. Styrene can also be found in some natural foods such as fruits and vegetables, meats, nuts, and some beverages (Centers for Disease Control and Prevention, 2014). The occurrence of styrene in many foods leads to exposure in the entire population as most people eat these foods or other foods derived from the styrene contaminated foods; however, the dietary exposure is slightly higher in children compared to adults (Silano et al., 2020). The higher exposure in children could be linked to healthier diets enforced by their parents or the lesser weight of children compared to adults. Styrene is also found in small quantities in food packaging (Silano et al., 2020). Food packaging is also another way that the entire population comes into contact with styrene.

Costs and Benefits

According to several studies conducted by toxicologists and research institutions, styrene has no major costs. Banton et al. (2019) stated that when styrene exposure was tested in rats, lung tumors formed. Researchers concluded that these tumors were rat-specific, and humans were not affected by this lung cancer when exposed to styrene. Smokers and factory workers who do not use proper respiratory equipment are at risk for higher exposures to styrene; however, these exposures can be limited and fixed if combated with the right safety precautions (Cao et al., 2018). Though styrene is leaked into food through packaging, the food has been deemed by the FDA to contain low and non-harmful amounts (What is polystyrene, 2022). The Styrene Information and Research Center (2022) stated that styrene is used in many protective equipment such as military armor and bicycle helmets. Styrene has proven to be the best material to use for these types of protective equipment and causes no exposure when using the equipment. They also stated that styrene-based products contribute to the reduction of greenhouse gas release. Styrene is also used to make watercraft machinery. The use of styrene in these products reduces the need for costly natural resources (Styrene Information and Research Center, 2022). Several billion pounds of styrene are made and used every year to make products such as rubber, insulation, fiberglass, plastic, food containers, pipes, and automobile parts, etc. These are all valuable products for individuals worldwide (Centers for Disease Control and Prevention, 2014).

Final Perspective

The group came to a final decision and a conclusion was reached that the chemical styrene should not be banned in the United States. Although some research has found that styrene may be linked to unhealthy exposure and some sicknesses, styrene is not a single contributing factor to large numbers of deaths in the United States. Styrene is a colorless liquid that gives off a sweet smell when in its pure form but in a factory setting, where it contains various aldehydes, it gives off a much more distinct and unforgiving odor (CDC, 2014). Styrene is mainly seen in a factory and manufacturing setting. Studies have shown that there has not been a single death as seen in any of the studies that were examined that could confidently be traced back to styrene, styrene has some adverse effects; however, these adverse effects are not a concern for the average American, they are limited to mainly factory workers in the fiber-reinforced polymer industry, the manufacturing of styrene monomer and polystyrene, and through the production of synthetic rubber (styrene-butadiene rubber, SBR). Also, when tested for cancerous effects in mice Banton et al. (2019) concluded that the lung tumors rats experienced when exposed to styrene posed no threats to humans. Styrene exposure is not a serious threat, and the average American is at minimal risk for styrene exposure daily. The plastic factory workers are not the only people who are at risk. The plastic factory workers' families are also at risk, without the proper protection, their family members are at a higher risk of developing tumors later on in life, especially of the lymphatic and the hematopoietic tissues.

The main route of exposure to styrene is through inhalation; exposure to styrene through dermal absorption and ingestion are not significant routes of exposure and studies have shown that these routes of exposure do not pose a serious risk. It is not sensible to ban styrene due to the minimal threat styrene poses. These minimal threats caused by styrene exposure can be nearly 100% eliminated by the use of protective gear in factories, this will protect our most at-risk group of individuals. Most styrene exposure can be minimized or eliminated through protective gear except for exposure through foods and beverages. Foods and beverages can be contaminated with styrene via the leaching of the chemical from the packaging the foods and beverages are stored in. The FDA has recently deemed oral exposure to styrene through food, beverages, and packaging as safe and not a cause for concern (What is polystyrene, 2022). The current regulations preventing styrene from affecting the body allows a safe workplace for industry workers, as well as the public consumption from plastic sources. Important organizations such as the EPA and OSHA implement regulations to prevent the harmful exposure of the chemical and with those regulations in place and the known effects the consumers of styrene products are not in harm by being exposed to styrene within the distinguished parameters. Styrene is also a valuable resource in producing many pieces of protective equipment and watercraft. Without styrene these valuable materials certainly will become much less effective and cause more harm than the chemical itself.

Overall, our group has come to the conclusion that the chemical in question, styrene, does not pose a serious threat to the average person, the outdoor air contains anywhere from 0.06-4.6 parts per billion styrene while indoor air contains anywhere from 0.07-11.5 parts per billion styrene. Styrene’s potential threat does need to be taken into consideration with factory workers, especially people who work in the FRP (fiber-reinforced polymer) industry, the manufacturing of styrene monomer and polystyrene, the production of synthetic rubber (styrene-butadiene rubber, SBR) and other similar lines of work where styrene exposure is happening regularly (CDC, 2014). In the FRP industry, it was found that workers developed lung and respiratory cancer at a slightly higher rate than the general population; however, it was strongly suggested that these results were not due to the over-exposure of styrene (Banton et al., 2019). Among all of those factory workers, styrene only poses a small threat through the inhalation route of exposure. Exposure through ingestion and dermal absorption are in no way significant routes of exposure that lead to adverse health effects. Styrene should not be banned in the United States, it does not pose a serious threat to the average American, and the factory workers it does impact can protect themselves by using protective equipment to protect them from inhalation exposure to styrene.

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