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METHYLENE CHLORIDE: UNDERSTANDING ITS ENVIRONMENTAL IMPACT, USE IN FOOD AND BEVERAGES, AND IMPACT ON HUMAN HEALTH

Rocco Casagrande[1]*

*Corresponding Author: **Rocco Casagrande,** ✉ jboisvert@daviespublicaffairs.com

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This brief report reviews US and international government regulations and guidelines for Methylene Chloride (MC) in air, drinking water, and food, investigates the known health hazards of MC, the potential risk to consumers from drinking decaffeinated coffee, and the potential harm to the environment from MC disposal.

Keywords: Food & beverage, Methylene chloride, Dichloromethane, Decaffeination process, Decaffeinated coffee, Chemical solvents, Food safety

INTRODUCTION

Methylene Chloride (MC) is used in the production of industrial chemicals, foods, and beverages, despite the fact that it is recognized as a health hazard and regulated by several agencies within the United States (US) and internationally. Several government bodies recognize MC as a probable cancer-causing agent, although the data linking MC to cancer in people is inconclusive. Workers exposed who inhale large amounts of MC can develop serious illnesses or die. Workers may also be injured by spilling MC on their skin or during disposal of MC.

Because of these reasons, regulatory authorities in the US and internationally set limits for how much MC workers can be exposed to on the job, how much MC is allowed in drinking water, and how much is allowed in foods and beverages.

Most consumers are exposed to MC through foods and beverages. MC is commonly used to decaffeinate coffee and create flavoring and spice extracts. Most MC is removed in the final steps of food and beverage production. The MC residue found in decaffeinated (decaf) coffee is low, and much of the residue is expected to evaporate in the brewing process. We estimate that the average American coffee drinker is expected to consume 50-fold less MC than the EPA suggests could be immediately harmful and 100,000-fold less than the amount that has been linked to cancer in rat studies. While residues of MC found in decaffeinated coffee are unlikely to pose a health risk, many brands no longer use the chemical. That being said, brands that still use MC to decaffeinate their beans rarely openly disclose this fact, complicating informed choices by consumers.

This brief report reviews US and international government regulations and guidelines for Methylene Chloride (MC) in air, drinking water, and food, investigates the known health hazards of MC, the potential risk to consumers from drinking decaffeinated coffee, and the potential harm to the environment from MC disposal.

METHYLENE CHLORIDE, EXPLAINED

Methylene Chloride (MC), also known as dichloromethane, is produced industrially and is widely used as a solvent in industrial processes (including paint stripping, pharmaceutical manufacturing, and metal cleaning) due to its ability to dissolve and extract other materials (Methylene Chloride (Dichloromethane), 2000; Dichloromethane, 2016; and Methylene Chloride, xxxx) MC is also used in the food

[1] Gryphon Scientific.

industry, including as a solvent to decaffeinate coffee beans and tea (Hulbert *et al.*, 1998).

HOW MC IS REGULATED

Despite its widespread use, MC is recognized as a health and environmental hazard and is regulated by several agencies within the US, including the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA). MC is also regulated in Canada, the European Union (EU), and other countries worldwide. US and international MC regulations are outlined below.

OSHA

OSHA regulates the maximum MC concentration allowed in air in a workplace for the entire work day and for any 15-minute period during the workday (https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1052). These limits were set as concentrations 1,000 fold greater than the MC found in polluted cities and near hazardous waste sites (Toxicological Profile for Methylene Chloride, 2000; and Methylene Chloride, 2018).

NIOSH

Because NIOSH recognizes MC as a possibly cancer-causing chemical, it recommends that exposure to workers be reduced to the lowest feasible limit.

EPA

Because of the potential for MC to contaminate drinking water from hazardous waste sites and from drug and chemical factories, the EPA sets regulatory limits through the National Primary Drinking Water Regulations. The EPA has also identified MC as a probable cancer-causing chemical and therefore has set a “goal” (a non-enforceable limit) that drinking water have no detectable MC. The highest level that is allowed is 0.005 milligrams per liter of water.

FDA

The FDA regulates MC as a “secondary direct food additive,” which is defined as an additive that is used in the process of making food that does not affect the finished food (unlike other additives such as flavoring agents). While existing FDA rules generally prohibit a chemical’s use as a food additive if it is found to cause cancer in either humans or animals, the FDA has concluded that the risk of cancer in consumers of these products is less than one in a million (in fact, one in 12 million) (Picut and Parker, 1992). Therefore, the FDA has specified certain foods can contain MC and has set maximum levels for MC residues in these three foods (Table 1 below).

Table 1: Permissible Levels of MC in Spice Oleoresins, Hops Extract, and Decaffeinated Coffee

Food	Permissible Level of MC
Spice oleoresins (pure liquid spice extracts)	Total of all solvent residues (including MC) is not to exceed 30 ppm.
Hops extract	MC is not to exceed 2.2% (22,000 ppm), provided that the hops extract is added to the wort before or during the cooking and manufacture of beer and the label of the hops extract identifies MC.
Decaffeinated roasted or instant coffee	MC is not to exceed 10 ppm (0.001%).

Canadian Government

The 1999 Canadian Environmental Protection Act allows the Canadian government to regulate the control and/or release of toxic substances including MC, due to its potential harm to both the environment and human health (Toxic Substances List: Dichloromethane, 2017). Therefore, containers that hold MC are required to be labeled (Methylene Chloride, 2019). The occupational exposure limits are similar to those of OSHA and the limit for the amount of MC allowed in drinking water is 100-fold lower than the EPA allows. Maximum residue limits of MC in food set by the Canadian government are similar to those delineated by the US FDA (Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Dichloromethane, 2015).

The European Union

The Volatile Organic Compound (VOC) Solvent Emissions Directive was implemented between 2007 and 2010 to reduce industrial emissions of VOCs such as MC. The EU banned the use of paint strippers containing MC in 2009 for both consumer and professional use but allowed certain industrial applications to continue if improved safety measures were implemented. Occupational exposure limits within the EU vary by country but are comparable to those put forth by OSHA. The EU specifies that there must be less than 2 ppm of MC in roasted decaffeinated coffee and 5 ppm in tea, limits that are stricter than those of the US and Canada (Directive 2009/32/EC of the European Parliament and of the Council, 2009).

Other Countries Worldwide

Australia and New Zealand permit the use of MC for the production of flavoring substances and decaffeinated coffee and tea. The maximum permitted level of MC residue in these foods is set at 2 ppm, which is similar to the limits set in the EU (Australia New Zealand Food Standards Code - Schedule 18 - Processing Aids, 2015). Japan and South Korea, two countries with strong consumer protection laws, completely ban the use of MC for coffee decaffeination and prohibit the import of coffee decaffeinated with MC (https://www.ffcr.or.jp/en/documents/index.html; Risk Reduction Monograph No. 2: Methylene Chloride Background and National Experience with Reducing Risk, 1994; and Request for Identification of Food Additives (Magnesium Stearate, Methylene Chloride, 2001). That being said, these countries do permit the use of MC in the production of spice extracts.

HEALTH HAZARDS

In industrial settings, people can be exposed to MC by breathing it in, spilling it on unprotected skin, or accidentally consuming it. Concentrations of MC in the air greater far exceeding the concentrations allowed by government regulations can lead to immediate illness and even death. Symptoms of poisoning by MC can include, but are not limited to, dizziness, fatigue, hearing loss, and fluid in the lungs (https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+66). Workers have died in accidents when MC concentrations reached levels more than a million-fold greater than government regulations allow. Spills of MC on the skin can lead to irritation, and if not removed soon after contact, MC can cause chemical burns. If MC is burned during disposal, toxic gases can be produced, and accidents have resulted in the poisoning of workers (https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+66).

There has never been a case recorded of a worker becoming seriously ill after accidentally eating MC. The risk to people consuming MC has been estimated using data from a two-year drinking water study conducted in rats by the EPA's Integrated Risk Information System (IRIS). This study concluded that a full-grown person could consume more than 10 milligrams of MC each day without any appreciable risk of illness over their lifetime (Toxicology Data Network, 2014). Importantly, this study did not address cancer risk.

In a review of the literature conducted by the US Department of Health and Human Services, "no information was found regarding the cancer-causing effects of methylene chloride in humans after oral exposure" [i.e., eating or drinking MC]. Studies in mice and rats show no *conclusive* relationship between consumption of MC and an increased risk of cancer, but suggest a risk may exist. For example, in one study, liver tumors were observed in rats that ingested more than 50 milligrams of MC every day for two years. However, the rats unexposed to MC sometimes developed liver tumors at a similar rate (Serota *et al.*, 1986a; and Dichloromethane, 2011). A third study fed rats more than 100 milligrams of MC every day for more than one year. In this study, the rats that were fed MC developed lung tumors at greater rates than the rats that did not eat MC (Serota *et al.*, 1986b). From this data, the US Department of Health and Human Services determined that MC "may reasonably be anticipated to be a cancer-causing chemical." The EPA has identified MC as a "probable cancer-causing agent in humans." NIOSH considers MC as a "possible cancer-causing substance in the workplace," and The International Agency for Research on Cancer (IARC) has classified MC as "possibly causing cancer in humans."

WHAT MC'S PRESENCE IN DECAFFEINATED COFFEE MEANS FOR HUMAN HEALTH

To put this scientific data in context, we estimated the amount of MC an average American coffee drinker would consume and compared this to the limits described above. Several studies conducted in the 1980s investigated the residual levels of MC in decaffeinated coffee beans. Most studies examining the amount of MC in decaffeinated coffee found less than 1 ppm of MC in beans, but one study that tested 15 different brands found concentrations as high as 4 ppm (Maltoni *et al.*, 1988). Even this level of MC is less than half the permissible level of MC in decaffeinated coffee according to the FDA.

Given that:

- Americans who drink coffee consume an average of 3.1 cups of coffee a day and the average size of a cup is nine fluid ounces (Page and Charbonneau, 1984).
- Two tablespoons of ground coffee beans should be used for every six fluid ounces of water (Coffee by the Numbers, 2010).
- Coffee weighs five grams per tablespoon.
- Therefore, an average American coffee drinker uses 9.3 tablespoons of ground coffee beans a day.

If we assume that the coffee used is from the brand with the highest recorded concentration of MC (4 ppm of MC), then the average person would consume less than 0.2 mg of MC per day if all the MC in the beans ended up in the cup of brewed coffee and did not evaporate during brewing. Because MC starts to vaporize at just above room temperature and coffee is brewed near the boiling point of water, some of the very small amount that remains in the beans is likely vaporized during the brewing process (https://athome.starbucks.com/get-to-know-the-four-fundamentals/).

Even assuming that someone drinks coffee from the brand with the most residual MC every day, this person would still drink 50-fold less MC than the amount the EPA's Integrated Risk Information System says humans can drink every day without an appreciable risk for all illnesses except cancer during a lifetime. Also, this amount consumed by a coffee drinker is nearly 100,000-fold less than the amount used in rodent studies that did not conclusively show a cancer risk. For this reason, the average consumer is unlikely to be harmed by the MC consumed in decaffeinated coffee.

HOW MC IMPACTS THE ENVIRONMENT

In addition to risks to human health, MC may pose a risk to the environment. About 80% of MC produced globally is eventually released into the atmosphere, accounting for about half a million tons of MC per year in the early 1990s but dropping since (https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-dichloromethane.html; McCulloch and Midgley, 1996; and Driftaway Coffee, 2015). This decline in use is attributed to industry's attempts to find alternatives for MC after the government concluded that it was possibly associated with the development of cancer. The vast majority of MC used globally is for industrial purposes (such as cleaning metal) and the amount consumed industrially in a day exceeds the amount used to decaffeinate coffee in an entire year. Moreover, much of the MC used to decaffeinate coffee is recaptured at the end of the process to be reused (https://www.atsdr.cdc.gov/ToxProfiles/tp14-c4.pdf).

Although MC is capable of destroying ozone in the laboratory, MC usually reacts with other pollutants in the lower atmosphere, and rarely reaches the ozone layer in the upper atmosphere (Lee, 1991). For this reason, it is not considered an ozone-depleting substance by most government bodies, including the US EPA (http://apps.sepa.org.uk/spripa/Pages/SubstanceInformation.aspx?pid=72) and the Canadian government (https://www.epa.gov/ozone-layer-protection/ozone-depleting-substances). Although about 10% of MC released into the environment reaches the soil or water sources, MC in water or soil quickly evaporates (Priority Substances List Assessment Report, Government of Canada. 1993; and Schlosser PM *et al.* 2015). Moreover, the effects of MC exposure on plants and most marine life are relatively minor (International Programme on Chemical Safety, 1996; and Agency for Toxic Substances and Disease Registry, 2015). For these reasons, environmental regulation is seemingly driven by the association of MC with a modest cancer risk.

COFFEE COMPANIES THAT USE METHYLENE CHLORIDE: WHAT WE DO AND DON'T KNOW

Given the potential health risks that MC poses to consumers, consumers may choose to avoid products made with MC. Several other options for decaffeination exist. Decaffeination can be performed using another FDA-approved solvent, ethyl acetate (http://www.npi.gov.au/resource/dichloromethane). Other decaffeination methods include decaffeinating using carbon dioxide as a solvent, or decaffeination using the "water process." (Methylene Chloride, 2006). However, determining which brands use MC for decaffeination and which do not is difficult as almost all brands that use MC do not advertise that fact. The FDA does not require MC-based decaffeination to be listed on the label of the product.

We researched information on the largest 20 coffee companies by extensively reading their product information. We found that approximately half claim to use a water- or carbon dioxide-based method. The rest do not state what process is used. These companies presumably use MC, which is reinforced by the presence of consumer complaints on various blogs. Some of the major brands use a water-based method for some roasts and MC for others. Our results were reinforced by published studies that report that while the use of MC is less common today than in the 1980s, it is still used by several major brands (Ramalakshmi and Raghaven, 1999).

CONCLUSION

MC can pose both a human health and environmental hazard. Government regulations and guidelines, including exposure limits and proper disposal methods, help reduce the risk to the public. Most reported sicknesses from MC exposure are in industrial workers handling large quantities of MC who accidentally breathe it in. In contrast, the American public is generally exposed to doses so low that they are very unlikely to result in any harmful health effects. Although data on the links between MC and cancer are inconclusive, studies suggest that the minute amount of MC remaining in decaffeinated coffee is unlikely to increase the risk of cancer in consumers. It is, however, challenging for consumers to discern which popular coffee brands use MC in their decaffeinating processes. The fact that coffee companies often do not disclose the use of MC frustrates any consumer who wants to understand the full extent of the environmental impact of the coffee they choose. Given consumer concerns over the potentially worrisome characteristics of MC, better labeling of decaffeinated coffee is needed to inform the public and improve transparency.

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