

► Una estimación de la exposición a los antimicrobianos triclosán y triclocarbán a través de los hábitos diarios

An estimation of the exposure to antimicrobials TRICLOSAN AND TRICLOCARBAN THROUGH DAILY HABITS

Por:  Regina Mijares Fajardo · David Eduardo Guevara Polo



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◆◆ ABSTRACT

Triclosan (TCS) and triclocarban (TCC) are widely used bactericides that can be found in several daily use products. However, they have been associated with numerous environmental and public health issues. Epidemiological studies have reported that humans are greatly exposed to these compounds. Therefore, the objective of this work is to compute the risk exposure given the reference dose of both contaminants, considering different daily habits. Additionally, the average amount of TCS and TCC in human blood is computed, and the processes of bioaccumulation, biomagnification, and bioaugmentation are discussed. Results show that the overall exposure risk of TCS and TCC is 0.033, which is equivalent to a probability of 1 in 30 of developing adverse effects. This is far beyond the acceptable risk of a chemical compound. Also, a gap in the literature was found because both compounds may play a role in cancer development, and hence, a risk assessment approach is necessary for these compounds.

◆◆ KEY WORDS:

Triclosan · Triclocarban · Risk exposure · Dose

◆◆ RESUMEN

El triclosán (TCS) y el triclocarbán (TCC) son bactericidas de uso generalizado que se pueden en-

contrar en varios productos de uso diario. Sin embargo, éstos se han asociado con numerosos problemas ambientales y de salud pública. Estudios epidemiológicos han reportado que las personas hemos estado ampliamente expuestas a tales compuestos. Por esta razón, el objetivo de este trabajo es calcular el riesgo de exposición dada la dosis de referencia de ambos contaminantes, considerando diferentes hábitos cotidianos. Tras computar la cantidad promedio de TCS y TCC en sangre humana, a continuación se comenta sobre los procesos de bioacumulación, biomagnificación y bioaugmentación con el fin de resaltar los daños potenciales que estos compuestos pueden implicar. Los resultados muestran que el riesgo de exposición general de TCS y TCC es 0.033, lo que equivale a una probabilidad de uno sobre treinta de desarrollar efectos adversos. Esto va mucho más allá del riesgo aceptable en un compuesto químico. Adicionalmente, se encontró que existe una brecha en la literatura debido a que ambos compuestos podrían desempeñar un papel en el desarrollo del cáncer y, por consecuencia, se requiere un enfoque de evaluación de riesgo para estos compuestos.

◆◆ PALABRAS CLAVE

Triclosán · Triclocarbán · Riesgo por exposición · Dosis

A graphic of a blue soap bar with the word "SOAP" written in white capital letters on a dark blue background.The number 16 is displayed in white on a dark blue arrow-shaped background pointing to the right.

Mayo - Agosto 2023

A decorative icon consisting of a dark blue semi-circle with a white crescent shape inside, resembling a stylized 'U' or a drop.

INTRODUCTION

The polychlorinated aromatic antimicrobials triclosan (TCS) and triclocarban (TCC) are in widespread use for killing microorganisms indiscriminately, rapidly, and through nonspecific action. As a result, they can be found in various products such as soaps, detergents, clothing, carpets, paints, plastics, toys, school supplies, and pacifiers (Halden, 2014). In September 2016, the U.S. Food and Drug Administration (FDA) banned nineteen antimicrobial ingredients, including TCS and TCC (FDA, 2016).

TCS has been associated with endocrine disruption effects (Fang *et al.*, 2010) and has been shown to be a slow-binding inhibitor of human and goose type I fatty acid synthase, as well as a partial inhibitor enoyl-reductase activity type I fatty acid synthase (Liu *et al.*, 2002). Additionally, it has been reported to promote bacterial resistance (Chen *et al.*, 2018).

Numerous epidemiological studies have documented the detection of TCS in urine, blood, and breast milk in different regions of the world, suggesting that the general population is exposed to TCS (Yueh & Tukey, 2016). There is strong evidence of the toxicity of TCS and TCC, as well as the exposure through ingestion and dermal contact in humans. Therefore, it is relevant to study the health risks associated with these chemical compounds. The objective of this work is to compute the risk of developing noncarcinogenic effects in the human body due to exposure to TCS and TCC in daily habits. Carcinogenic effects are not evaluated since TCS and TCC are not reported in the Integrated Risk Information System (IRIS) of the United States Environmental Protection Agency (USEPA), and neither their cancer potentials have been assessed by the International Agency for Research on Cancer or the U.S. National Toxicology Program 14th report on carcinogens (National Center for Biotechnology Information, 2019a, 2019b). Therefore, no slope factors (SF) are available to calculate the carcinogenic risk of these chemicals. However, both TCS and TCC may play a role in cancer development (Yang *et al.*, 2020; Rehman *et al.*, 2021; Wang *et al.*, 2023; Zhang *et al.*, 2023). Considering these preliminary findings, an approach for cancer risk assessment may be necessary in the future.

METHODOLOGY

Essentially, the safety level of intake can be computed using criteria from the United States Environmental Protection Agency (USEPA) or the World Health Organization (WHO). The USEPA criteria, described by the reference dose (RfD), and the WHO criteria, described by the acceptable daily intake (ADI), can be used for this purpose. In this article, the criteria and equation proposed by the USEPA (1989) are applied. The overall risk of developing adverse health effects from exposure to TCS and TCC is calculated by considering three products that are relevant for consumers in the United States: carrots, tomatoes (which together account for 42 % of vegetable consumption (USDA, 2014)), and meat (including red meat and poultry). The average consumption rate of these products is derived from the population of the United States as a reference. These consumption rates are then multiplied by the TCS and TCC concentrations in each product to obtain the daily intake. Subsequently, the daily intake is divided by the body weight to obtain the daily dose. Here, a 70-kg person is used as a reference.

Similarly, the consumption of drinking water containing TCS and TCC is considered, as well as the average inhalation of both chemicals. To calculate the inhalation intake, the average amount of inhaled air is multiplied by the concentration of particles of breathable size (PM10) in the air. Once the average amount of inhaled dust is determined, it is multiplied by the average TCS and TCC concentration in dust to obtain the intake. The intake is then divided by the body weight to calculate the dose.

Additionally, the dermal contact and sorption of TCS and TCC are evaluated by considering a daily 15-minute shower using soaps that contain these substances. The absorbed dose through dermal contact with water is calculated using Equation 1 (USEPA, 1989):

EQ.(1)

$$AD = \frac{CW \cdot SA \cdot PC \cdot ET \cdot EF \cdot ED \cdot 1 \times 10^{-3}}{BW \cdot AT}$$

One
out of every
thirty
individuals may
experience
adverse health
effects if the
included daily
exposure habits
are considered.

Some of the
potential health
effects include
endocrine
disruption, dermal
pathologies, and
cross-resistance
to antibiotics.

Where AD is the absorbed dose in mg/kg-day. CW is the chemical concentration in water, measured in mg/L. SA is the skin surface area available for contact in cm^2 . PC is the chemical-specific dermal permeability constant in cm/h . ET is the exposure time in h/day. EF is the exposure frequency in days/year. ED is the exposure duration in years. BW is the body weight in kg and AT is the averaging time in days. In this way, the result yields in $\text{mg}/(\text{kg}\cdot\text{day})$.

Once the doses of TCS and TCC from food consumption, water consumption, inhalation, and dermal absorption are calculated, the risk is determined by dividing these doses by their respective reference dose (RfD). The human reference dose, as defined by the USEPA (1993), is an estimate of "a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime". The reported RfD for TCS is 0.30 mg/kg-day (USEPA, 1998), and the reported RfD for TCC is 0.25 mg/kg-day (Snyder & O'Connor, 2013). In both cases, the RfD is calculated as the No Observed Adverse Effect Level (NOAEL) divided by the product of uncertainty factors and modifying factors, which encompass the transfer of toxicological data from animals to humans, sensitivity, and other sources of uncertainty (Davis & Masten, 2014).

Finally, to compute the amount of TCS and TCC in the blood, the total blood volume is estimated using Equation 2 (Hoffman *et al.*, 2018):

$$\text{EQ.(2)} \quad V = 0.3669H^3 + 0.03219W + 0.6041$$

Where V is the total blood volume for males in litres, H is the height in meters, and W is the weight in kilograms. Afterwards, the volume is multiplied by reported TCS and TCC concentrations in plasma after exposure to an average dose. In this study, the reference subject is an adult whose height and weight are 1.70 meters and 70 kilograms, respectively.

RESULTS

The average daily consumption of tap and bottled drinking water for men and women between the ages of 20 and 39 is reported to be 4.9 cups (1.16 L) (Sebastian *et al.*, 2011). Additionally, the maximum concentration of TCS reported in U.S. drinking water is 6.4 ng/L (Benotti *et al.*, 2009). However, it has also been reported that the maximum concentration of TCS in drinking water could reach as high as 130 ng/L, and the maximum concentration of TCC can be up to 102 ng/L (Shen *et al.*, 2012). It is important to note that the concentration of TCS and TCC in drinking water can vary depending on several variables; however, for this study, a conservative value will be used to avoid underestimating the risk.

The per capita consumption of carrots in the United States was reported to be 11.87 pounds in 2004 (Lucier & Lin, 2007). Moreover, the accumulation of TCS and TCC in the edible tissues of carrots, such as the skin and core, can reach up to 900 ng/g and 1100 ng/g, respectively (Fu *et al.*, 2016).

The consumption of tomatoes in the United States is second only to potatoes (Reimers & Keast, 2016), making it relevant to consider them in this study. The accumulation of



THE SAFETY LEVEL OF INTAKE CAN BE COMPUTED USING CRITERIA FROM THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA) OR THE WORLD HEALTH ORGANIZATION (WHO). THE USEPA CRITERIA, DESCRIBED BY THE REFERENCE DOSE (RFD), AND THE WHO CRITERIA, DESCRIBED BY THE ACCEPTABLE DAILY INTAKE (ADI).

tcc in the shoot of tomatoes is reported to be 0.53 mg/kg, while the accumulation of tcs is 1.75 mg/kg (Mathews *et al.*, 2014). The average intake of tomatoes in the U.S. is 2.47 cups per day (Reimers & Keast, 2016).

The per capita consumption of red meat and poultry in the United States for 2018 was reported to be 219.5 pounds (United States Department of Agriculture, 2019). Interestingly, when searching for triclosan concentrations, the results yield publications related to food engineering, where tcs is used as a bactericide in plastic packaging. The predicted concentration of tcs in beef, pork, and chicken is 18.65×10^{-3} mg/kg, while the concentration of tcc is 0.76 ng/g (Verslycke *et al.*, 2016; Kimura, 2019).

On the other hand, the recommended long-term exposure value for air inhalation for adults between 21 and 61 years old is $21.3 \text{ m}^3/\text{day}$ (Environmental Protection Agency, 2011). The average concentration of PM_{10} in the air in the United States in 2018 was $63.9 \text{ } \mu\text{g}/\text{m}^3$ (Environmental Protection Agency, 2019). The mean concentration of tcs in indoor dust environments is reported to be 484 ng/g (Geens *et al.*, 2009), while the mean concentration of tcc in dust is 270 ng/g (Chen *et al.*, 2018).

Moreover, to evaluate the absorbed dose through dermal contact Equation 1 is used. Here, the chemical concentration in water cw is taken as 130×10^{-6} mg/L for tcs and 102×10^{-6} mg/L for tcc as reported by Shen *et al.* (2012). The skin surface area available for contact sa is considered to be 19400 cm^2 (Froom, 2008). The chemical-specific dermal permeability constant pc is 0.0692 cm/h for tcs (Verslycke *et al.*, 2016) and for tcc, the dermal permeability constant derived by the Scientific Committee on Consumer Products (sccp, 2004) is within a range between 1.48×10^{-8} and 7.08×10^{-8} cm/h. In this work, a conservative value was used to prevent an underestimation of the absorbed dose. The exposure time ET is 0.25 h/day, considering a 15-minute shower on average. The exposure frequency EF is 365 days/year considering a daily shower. The exposure duration ED is $1/365 = 2.74 \times 10^{-3}$ in years, considering a duration of 1 day. The body weight BW is taken as 70 kg as a reference and the average time AT is 1 day.

In this way, the absorbed dose through dermal contact yields around 6.23×10^{-7} mg/kg-day for triclosan and 5.01×10^{-13} mg/kg-day for triclocarban.

Dose of TCS and TCC absorbed through dermal contact (using equation 1)

$$AD_{TCS} = \frac{130 \times 10^{-6} \cdot 19400 \cdot 0.0692 \cdot 0.25 \cdot 365 \cdot 2.74 \times 10^{-3} \cdot 1 \times 10^{-3}}{70 \cdot 1}$$

$$= 6.23 \times 10^{-7} \frac{\text{mg}}{\text{kg} - \text{day}}$$

$$AD_{TCC} = \frac{102 \times 10^{-6} \cdot 19400 \cdot 7.08 \times 10^{-8} \cdot 0.25 \cdot 365 \cdot 2.74 \times 10^{-3} \cdot 1 \times 10^{-3}}{70 \cdot 1}$$

$$= 5.01 \times 10^{-13} \frac{\text{mg}}{\text{kg} - \text{day}}$$

The analysis of TCS and TCC ingestion and inhalation is summarized in Tables 1 and 2. It can be observed that the risk of TCS exposure for a 70 kg adult person is 0.02377, while the risk of TCC exposure is 0.00927. Taking these data into account, the total risk for both compounds is calculated to be 0.033, which is equivalent to a probability of 1 in 30. It is important to note that the majority of TCS and TCC intake comes from food consumption rather than dermal exposure or drinking water ingestion.

Given the significant difference in the orders of magnitude of the risk estimates presented in Tables 1 and 2, it is interesting to visualize these results graphically. Figure 1 depicts the risk estimated from TCS exposure, while Figure 2 presents the risk estimated from TCC exposure. The y-axis in both plots is reported on a logarithmic scale, and all risk values are smaller than one. Therefore, the shorter the bar in Figures 1 and 2, the higher the risk for TCS and TCC exposure, respectively. Figure 1 illustrates that the highest risk from TCS exposure is associated with tomato consumption, followed by carrot consumption with a difference of more than one order of magnitude. Similarly, Figure 2 demonstrates that for TCC, the highest risk is linked to tomatoes, followed by carrots. By comparing both plots, it becomes evident that only meat and dermal contact display a change in the order of magnitude, and that the overall risk from TCS is higher than that from TCC.



IT IS IMPORTANT TO NOTE THAT THE MAJORITY OF TCS AND TCC INTAKE COMES FROM FOOD CONSUMPTION RATHER THAN DERMAL EXPOSURE OR DRINKING WATER INGESTION.

Table 1. TCS daily intake and risk.

Consumption			TCS Concentration	TCS Intake (mg/day)	TCS Dose [mg/(kg-day)]	Risk (RfD = 0.3 mg/(kg-day))
Drinking water	1.16 L/day	1.16 L/day	130.00 ng/L	1.51e-04	2.15e-06	7.18e-06
Carrots	11.87 lb/year	14.78 g/day	900.00 ng/g	1.33e-02	1.90e-04	6.34e-04
Tomatoes	2.47 cups/day	0.27 kg/day	1.75 mg/kg	4.81e-01	6.87e-03	2.29e-02
Meat	219.50 lb/year	0.27 kg/day	1.87E-02 mg/kg	5.10e-03	7.28e-05	2.43e-04
Dust	63.90 µg/m ³ air	1.36 mg/day	484.00 ng/g	6.59e-07	9.41e-09	3.14e-08
Air	21.30 m ³ /day	21.30 m ³ /day	Dermal contact		6.23e-07	2.08e-06
					7.13e-03	2.38e-02

Table 2. TCC daily intake and risk.

Consumption			TCC Concentration	TCC Intake (mg/day)	TCC Dose [mg/(kg-day)]	Risk (RfD = 0.25 mg/(kg-day))
Drinking water	1.16 L/day	1.16 L/day	102.00 ng/L	1.18e-04	1.69e-06	6.76e-06
Carrots	11.87 lb/year	14.78 g/day	1100.00 ng/g	1.63e-02	2.32e-04	9.29e-04
Tomatoes	2.47 cups/day	0.27 kg/day	0.53 mg/kg	1.46e-01	2.08e-03	8.32e-03
Meat	219.50 lb/year	0.27 kg/day	7.60E-04 mg/kg	2.08e-04	2.97e-06	1.19e-05
Dust	63.90 µg/m ³ air	0.00 g/day	270.00 ng/g	3.67e-07	5.25e-09	2.10e-08
Air	21.30 m ³ /day	21.30 m ³ /day	Dermal contact		5.01e-13	2.55e-12
					2.32e-03	9.27e-03

THE SHORTER THE BAR IN FIGURES 1 AND 2, THE HIGHER THE RISK FOR TCS AND TCC EXPOSURE.

Figure 1. Risk from TCS exposure through foods and other routes of exposure.

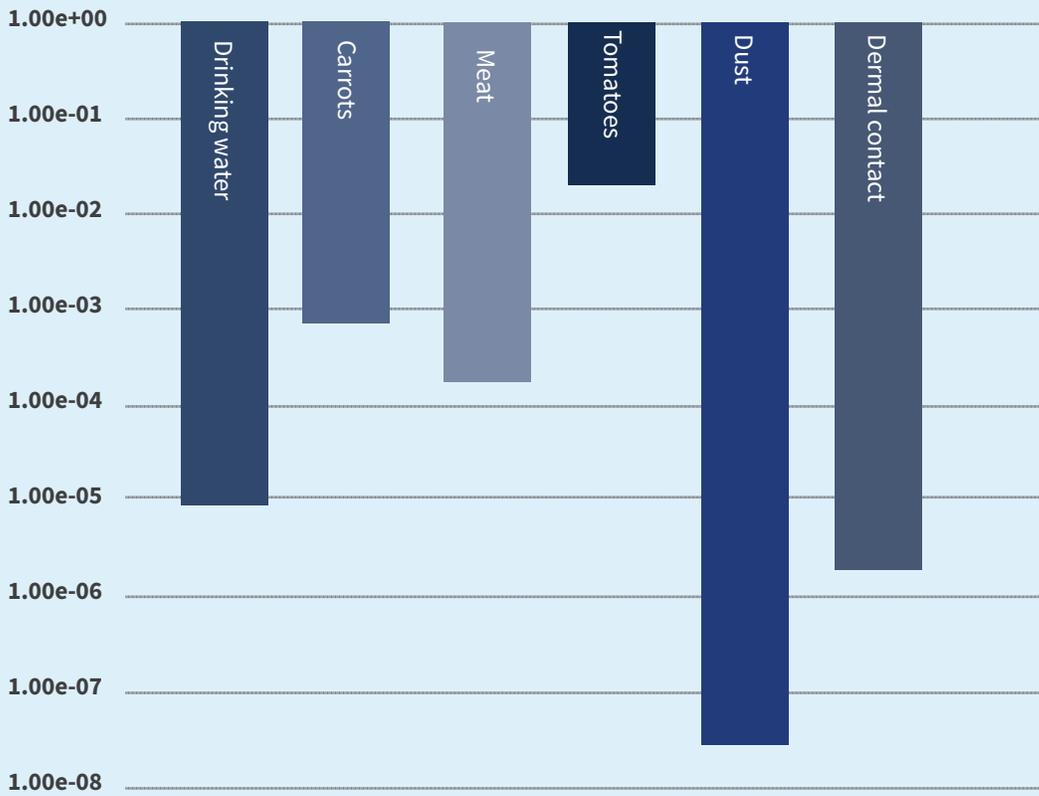
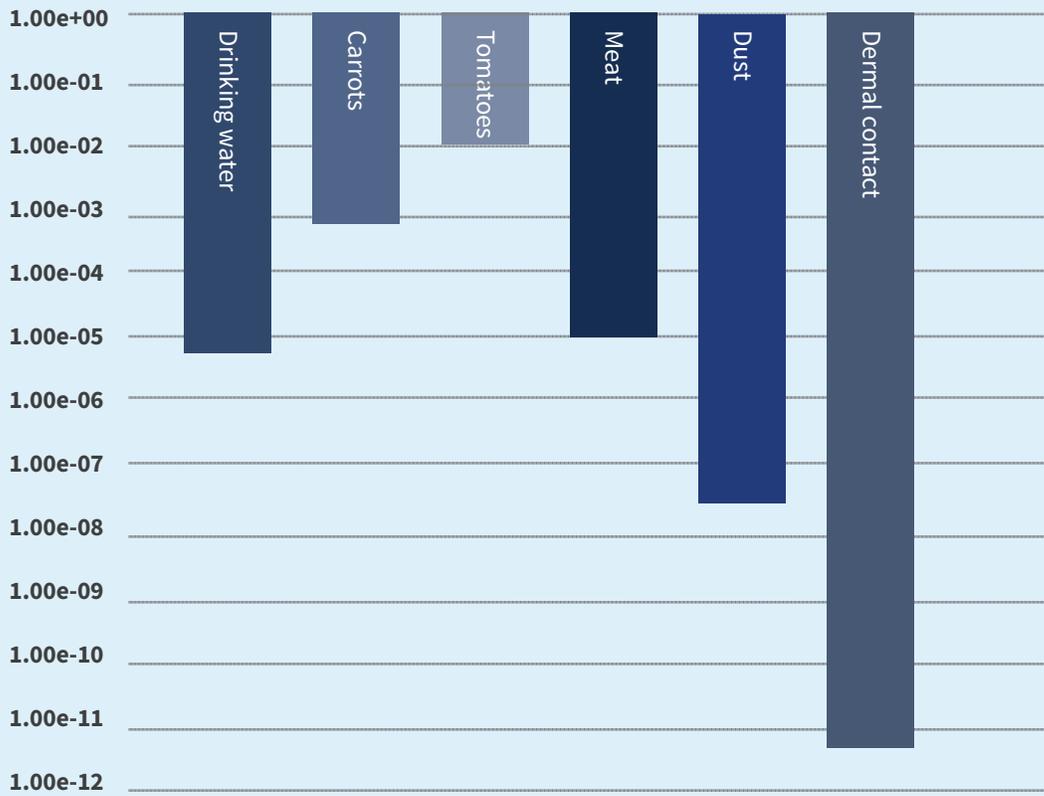


Figure 2. Risk from TCC exposure through foods and other routes of exposure.



Moreover, the composition of the risk of both TCS and TCC is described in Figures 3 and 4, although it is important to state that the risk can be extended to include more products and routes of exposure. The TCS risk shown in Figure 3 is composed 96 % by tomatoes, 3 % by carrots and 1 % by meat. Similarly, the TCC risk shown in Figure 4 is mainly composed by tomatoes (90 %) and carrots (10 %). In both cases, there is a small fraction, practically less than 1 %, that is composed by dermal contact, drinking water and dust.

Furthermore, in order to estimate the levels of TCS and TCC in human blood, an average adult with a height of 1.70 meters and a weight of 70 kilograms is used as a reference. Taking these factors into consideration, Equation 2 yields a blood volume of 4.7 liters. The maximum concentration of TCS in plasma after exposure to an average dose ranging from 49 to 67 micrograms per kilogram falls within the range of 170 to 267 micrograms per liter (Sandborgh-Englund *et al.*, 2006). Moreover, Sandborgh-Englund *et al.* (2006) discovered that TCS is rapidly absorbed from the gastrointestinal tract, and the pharmacokinetic profile indicates a rapid elimination pattern.

In addition, a concentration of 285 ± 5 nM was discovered in the blood of a regular user of TCC-containing soap (Schebb *et al.*, 2012). This concentration is equivalent to $89.9 \mu\text{g/L}$, which can be calculated using the molecular weight of TCC, which is 315.9 g/mol.

The results of the blood concentrations of TCC and TCS are summarized in Table 3. It is evident that by employing a conservative approach, the amount of TCS in the blood is estimated to be 1255 μg , while the amount of TCC in the blood is 422.53 μg . In other words, the mass of TCS in the blood is almost three times higher than that of TCC. This difference can be attributed to the more widespread use of TCS as a bactericide, as well as the availability of more literature regarding its characterization and concentration in the blood, which enhances the accuracy of these calculations.



THE MASS OF TCS IN THE BLOOD IS ALMOST THREE TIMES HIGHER THAN THAT OF TCC. THIS DIFFERENCE CAN BE ATTRIBUTED TO THE MORE WIDESPREAD USE OF TCS AS A BACTERICIDE.

Table 3. TCC and TCS concentration in blood.

Chemical Compound	Concentration in Blood ($\mu\text{g/L}$)	Blood Volume (L)	Mass in Blood (μg)
Triclosan	267	4.7	1255
Triclocarban	89.9	4.7	423

Figure 3. Triclosan (TCS) risk composition.

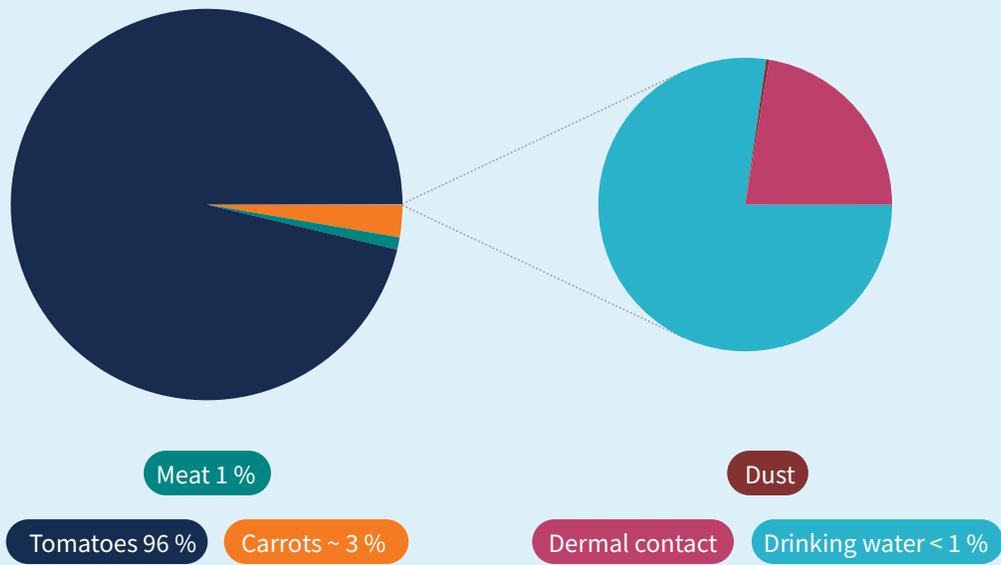
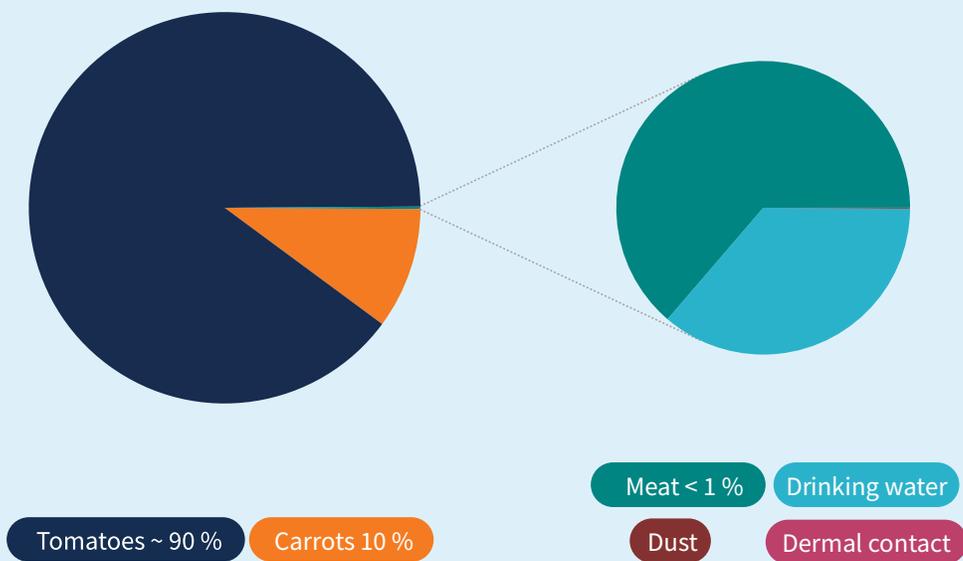
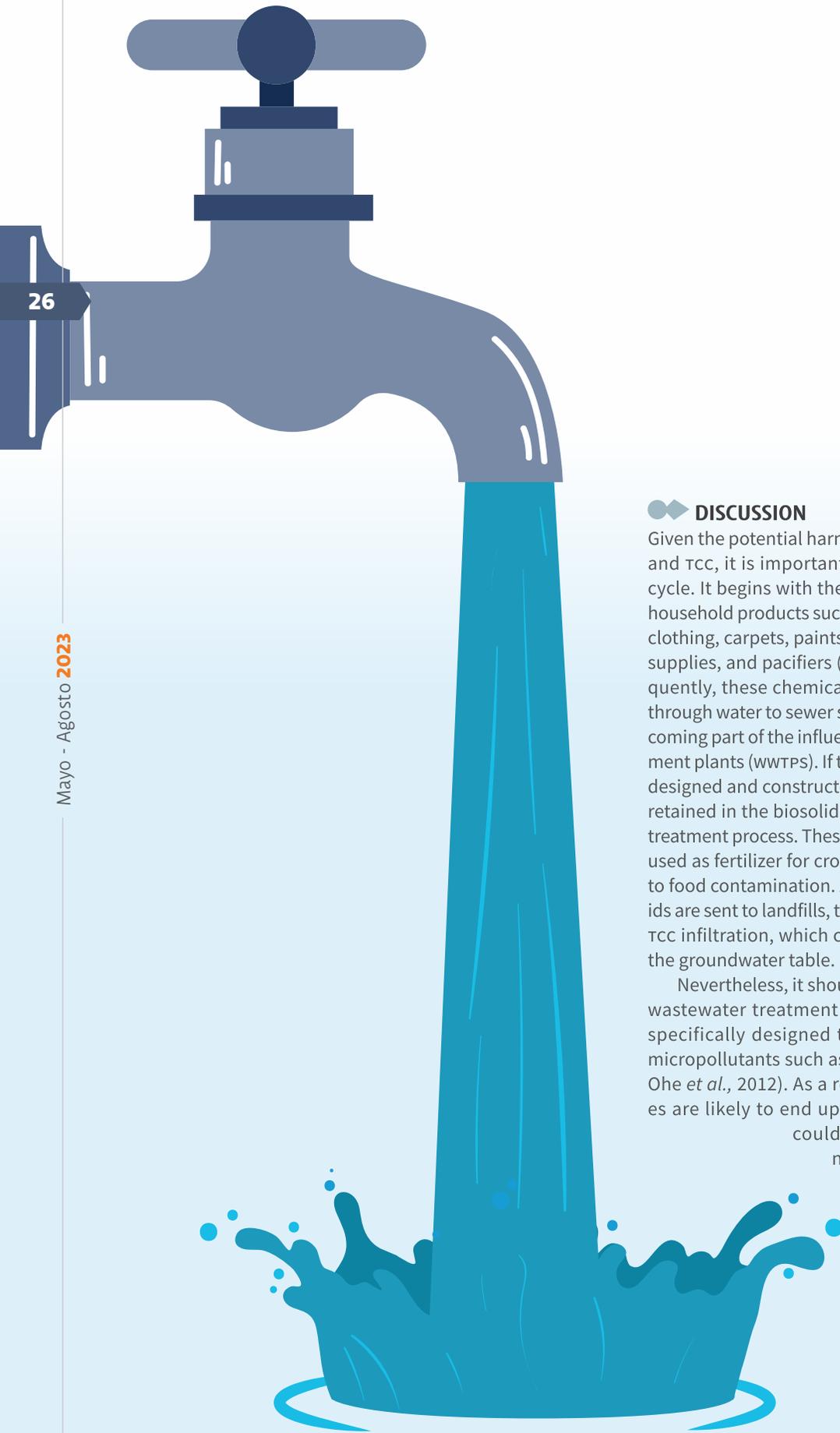


Figure 4. Triclocarban (TCC) risk composition.





◆ DISCUSSION

Given the potential harmful effects of both TCS and TCC, it is important to consider their life cycle. It begins with their presence in various household products such as soaps, detergents, clothing, carpets, paints, plastics, toys, school supplies, and pacifiers (Halden, 2014). Subsequently, these chemicals can be transported through water to sewer systems, ultimately becoming part of the influent in wastewater treatment plants (WWTPs). If the WWTPs are properly designed and constructed, TCS and TCC can be retained in the biosolids produced during the treatment process. These biosolids can then be used as fertilizer for crops, potentially leading to food contamination. Alternatively, if biosolids are sent to landfills, there is a risk of TCS and TCC infiltration, which could eventually reach the groundwater table.

Nevertheless, it should be noted that most wastewater treatment technologies are not specifically designed to effectively remove micropollutants such as TCS and TCC (Von der Ohe *et al.*, 2012). As a result, these substances are likely to end up in surface water and could eventually contaminate groundwater, posing a risk to potential sources of drinking water. Due to its high hydrophobicity, TCS has

TCS AND TCC LIFE CYCLE

1

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TCS and TCC can be retained in the biosolids produced during the treatment process, then can be used as fertilizer for crops, potentially leading to food contamination. If biosolids are sent to landfills, there is a risk of infiltration, which could eventually reach the groundwater table.

4

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the ability to accumulate in fatty tissues. For example, it has been found in fish samples. Furthermore, TCS is known to be biodegradable, photo-unstable, and reactive towards chlorine and ozone (Bedoux *et al.*, 2012), which can lead to the depletion of aquatic life in water bodies.

It may seem that TCS and TCC are primarily associated with water pollution due to their common transport medium throughout their life cycle. However, as previously mentioned, TCS can also be incorporated into soil through the application of biosolids (Corrotea *et al.*, 2016). Once in the soil, it can be absorbed by plant roots and subsequently become a pollutant in the food chain. Moreover, studies have also identified the presence of TCC and TCS in indoor air. Considering that individuals in developed countries spend over 90% of their time indoors (Chen *et al.*, 2018), both TCS and TCC pose air pollution concerns in indoor environments. In summary, TCS and TCC can be considered pollutants in water, soil, and air.

Additionally, it is important to discuss the potential for bioaccumulation of these chemical compounds. Bioaccumulation refers to the increase in the concentration of a chemical over time in living organisms, relative to its concentration in the environment. This occurs when the compound is retained in living tissues at a faster rate than it is metabolized (Davis & Masten, 2014). TCS has been found to potentially bioaccumulate

in plant tissues (Pannu *et al.*, 2013) as well as in the human body, leading to significant health problems (Nandikes *et al.*, 2022).

At the same time, it is important to consider the concept of biomagnification for these compounds. Biomagnification refers to the process by which a chemical accumulates in an organism at higher concentrations than those found in its food. It occurs when a chemical becomes increasingly concentrated as it moves up the food chain (Davis & Masten, 2014). According to Taiwo *et al.* (2022), biomagnification of TCS and TCC occurs in the food chain, although the scientific literature provides limited evidence of this phenomenon. Since humans consume TCS and TCC from various foods, biomagnification has the potential to result in higher concentrations in human blood compared to concentrations found in plant- and animal-derived foods. This possibility is supported by the occurrence of bioaccumulation.

Consequently, the potential exposure to TCS and TCC can be amplified through two mechanisms: bioaccumulation and daily intake, considering their widespread presence in a variety of personal care products. This increased exposure raises significant concerns regarding the potential harm to living tissues and disruption of the endocrine system. Further characterization of the risks associated with bioaccumulation and biomagnification is necessary to fully understand their impacts.

On the other hand, it is crucial to recognize that bioaugmentation presents a potential solution to the pollution issue posed by TCS and TCC. Bioaugmentation involves the addition of pre-grown microbial cultures to enhance microbial populations at a site, thereby improving contaminant cleanup efficiency and reducing cleanup time and costs (Speight, 2016). Studies



BIOAUGMENTATION PRESENTS A POTENTIAL SOLUTION TO THE POLLUTION ISSUE POSED BY TCS AND TCC. IT INVOLVES THE ADDITION OF PRE-GROWN MICROBIAL CULTURES TO ENHANCE MICROBIAL POPULATIONS AT A SITE, IMPROVING CONTAMINANT CLEANUP EFFICIENCY AND REDUCING CLEANUP TIME AND COSTS.

have shown that TCS can be biodegraded using acclimatized aerobic and anaerobic sludge, as well as isolated bacteria in a mineral salt medium (Veetil *et al.*, 2012). Similarly, TCC can be transformed under anoxic conditions using *Ochrobactrum* bacteria (Yun *et al.*, 2017). Therefore, bioaugmentation is a viable technique for the treatment of these chemical compounds in both wastewater and sludge.

CONCLUSIONS

In this study, an analysis was conducted to assess the risk of developing adverse health effects from exposure to TCS and TCC through daily habits. The risk was evaluated using the reported reference doses (RfDs) for both compounds. The daily doses of TCS and TCC were estimated based on the consumption of contaminated food products such as carrots, tomatoes, and meat, as well as contaminated drinking water. Inhalation rates and dermal exposure were also considered. Consumption rates were obtained from the United States population as a reference, considering the data availability. Additionally, the estimated quantities of these chemicals in human blood were determined.

In addition, certain comments were provided regarding the topics of bioaugmentation, bioaccumulation, and biomagnification, highlighting the potential hazards that TCS and TCC pose in terms of water, soil, and air pollution. The study suggests that bioaugmentation can be a viable alternative for treating TCS and TCC concentrations in wastewater and sludge.

Considering the lack of information regarding the carcinogenic risk of TCS and TCC, and the absence of slope factors (SF) reported in the literature, the assessment of carcinogenic effects was not conducted. However, given the emerging evidence suggesting a potential link between these compounds and cancer development, further investigation of this risk in future studies is necessary. Moreover, for non-carcinogenic effects, the daily intakes could be adjusted to food and water consumption rates in other countries, such as Mexico. Additionally, it is recommended to consider a wider variety of food products in future work.

Overall, the results of this study indicate that the risk of developing adverse health



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Riesgos Hidrometeorológicos, con sede en la UDLAP, y es miembro del Comité del Agua del Colegio de Ingenieros Civiles de México. Actualmente desarrolla su proyecto de investigación doctoral, en donde utiliza el enfoque de dinámica de sistemas para estudiar el efecto de oscilaciones climáticas en acuíferos.
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effects from exposure to TCS and TCC is 0.02377 and 0.00927, respectively, with a combined risk of 0.033 when both compounds are considered. This means that approximately one out of every thirty individuals may experience adverse health effects if the included daily exposure habits are considered. Some of the potential health effects include endocrine disruption, dermal pathologies, and cross-resistance to antibiotics. These findings emphasize the significant risk associated with TCS and TCC exposure, which explains why the FDA banned their use in 2016.

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