# Environmental Emergence of Triclosan

White Paper prepared by the Emerging Contaminants Workgroup
of the Santa Clara Basin Watershed Management Initiative (SCBWMI)[1]

January 2006

## Executive Summary

Antibacterial agents, such as triclosan, are common ingredients in many everyday household and personal care products. There is a growing concern about the emergence of these chemicals in the environment. The SCBWMI Emerging Contaminants Workgroup reviewed the state of knowledge regarding triclosan, the most common of these antibacterial agents. The Workgroup recommends the adoption of strategies to minimize the occurrence of antibacterial agents and their breakdown products in surface water. Proposed next steps, messages and audiences are presented in Section 5. Based on a comprehensive literature review, the SCBWMI Emerging Contaminants Workgroup draws the following conclusions:

- The American Medical Association has not endorsed the necessity or efficacy of triclosan and other antibacterial agents in personal care products (Section 1)
- Antibacterial agents and their degradation products are found in many tested U.S. surface waters, including San Francisco Bay (Section 2)
- One such agent, triclosan is acutely and chronically toxic to aquatic organisms (Section 3)
- Triclosan bioaccumulates in fish and human tissue (Section 3)
- Triclosan may degrade into other toxic compounds (Section 3)
- Triclosan may encourage antibiotic resistance in pathogenic bacteria. (Section 3).
- Physicians indicate that the best germ fighting measure continues to be the actual act of hand washing with regular soap, or for extra assurance, alcohol or peroxide-based hand sanitizers (Section 4)

**Emerging Contaminants Workgroup**
The Emerging Contaminants Workgroup was chartered at the request of the SCBWMI in 2001 to provide a forum to discuss issues related to endocrine disrupting compounds and recycled water. The workgroup has since broadened its scope to include all emerging contaminants of concern, not just those having endocrine disrupting effects. The workgroup is open to all interested parties. Participants include scientists, engineers, staff and managers from government and non-government organizations.

The purpose of the group is to collect and review information based on the best available science on emerging contaminants of concern in and around San Francisco Bay. The Workgroup has been successful in developing communication pieces for different audiences, including white papers for local government and non-governmental organizations' staff, and fact sheets for the general public.

**Audience and Purpose of White Papers**
The white papers are produced for regional and local government, as well as participating non-government organization staff, and are designed to provide a starting point for discussion regarding emerging contaminants found in and around San Francisco Bay. The papers provide an overview of research, current programs when applicable, and potential pollution prevention solutions that will allow interested parties to consider possible action items or next steps.

[1] For more information, contact: Stephanie Hughes, RMC (shughes@rmcwater.com; 408-240-8174); Jessie Denver, City of San Jose (jessie.denver@sanjoseca.gov; 408-277-3534; or Karin Didriksen North, City of Palo Alto (karin.north@cityofpaloalto.org; 650-494-7629).

## 1. Introduction

Triclosan[2] is registered as an antibacterial agent, bactericide, disinfectant, and fungicide. Triclosan use began in the 1970s as an antibacterial agent in soaps. Uses of triclosan have risen dramatically in the past few years. It appears this may be more of a marketing strategy than a medical necessity. Triclosan is now found in the following products:

- Hand soap
- Dish-washing products
- Laundry detergents and softeners
- Plastics (e.g., toys, cutting boards)
- Toothpaste
- Deodorants and antiperspirants
- Cosmetics
- Hair conditioners
- Impregnated sponges
- Pesticides (as an inert ingredient[3])

Triclosan, as well as other antibacterial agents and their degradation byproducts, are now found throughout the environment, including surface waters, soil, fish tissue, and human breast milk.[4] Despite increasing data reflecting the presence of triclosan in surface water, in conducting research for the development of this White Paper, no data was found to support the necessity or efficacy of antibacterial agents in consumer products.

Furthermore, the American Medical Association (AMA) has concerns about the use of these chemicals and has:

- Encouraged the U.S. Food and Drug Administration to study the issue.
- Stated that they will monitor the progress of the current FDA evaluation of the safety and effectiveness of antimicrobials for consumer use in over-the counter hand and body washes.
- Encouraged continued research on the use of common antimicrobials as ingredients in consumer products and their impact on the major public health problem of antimicrobial resistance.[5]

This White Paper details these issues and presents messages, identifies audiences, and suggests strategies to reduce unnecessary uses of antibacterial products.

## 2. Sources and Transport Pathways to Surface Water

According to the literature, triclosan has been detected in a variety of environmental media. In a 1999-2000 study by the U.S. Geological Survey, triclosan was found in 57 percent of the 139 U.S. waterways

---

[2] A related compound, triclocarban, is similarly used as an antibacterial agent. While not the focus of this white paper, due to limited available research, it is anticipated that it should be incorporated into public outreach messages regarding antibacterial agents.
[3] http://www.cdpr.ca.gov/cgi-bin/epa/mkepa3.pl?chems=054901&activeonly=on
[4] Swiss researchers found three out of five samples of human breast milk contained measurable concentrations of triclosan, at concentrations up to 30 μg/kg lipid weight. Adolfsson-Erici, M. Patterson, J.Parkkonen, and J.Sturve. (2000) Triclosan, A Commonly Used Bactercide Found in Human Milk and in the Aquatic Environment, in *Abstracts of Dioxin, 2000, 20th International Symposium on Halogenated Environmental Organic Pollutants and POP's: Monterey, CA.* , Volume 48, page 83
[5] L. Tan, N.H. Nielsen, D.C. Young, Z. Trizna for the Council on Scientific Affairs. *Use of antimicrobial agents in consumer products. Arch Dermatol.* 2002; 138: 1082-1086

that were thought to be susceptible to agriculture or urban activities.[6] The San Francisco Estuary Institute has also detected triclosan and its metabolites in San Francisco Bay (Bay) surface waters.[7]

Triclosan has been found in both surface water and wastewater. Surface water sources may include wastewater treatment plant effluent, urban stormwater, rural stormwater, and agricultural runoff.

The transport of triclosan to wastewater treatment plants occurs when people:

- Wash hands with antibacterial soap
- Hand wash dishes with antibacterial soap
- Clean with antibacterial products
- Use antibacterial products in a dishwasher
- Bathe or shower with antibacterial soap or shampoo
- Brush teeth with toothpaste containing antibacterial products
- Wash clothes with antibacterial products
- Wash antibacterial cutting boards

When domestic wastewater is treated before discharge to surface waters, there is evidence that up to 95 percent of triclosan is removed via the wastewater treatment plant process.[8] This removal efficiency is dependent on treatment plant operations. Swiss researchers observed a 94 percent removal rate of triclosan at wastewater treatment operations that employed mechanical clarification, biological treatment or nitrification, flocculation and filtration. The researchers estimated that 79 percent of the triclosan was removed via biological degradation while 15 percent adsorbed to the sludge. The remaining 6 percent in the effluent resulted in a concentration of 42 ng/Liter.[9]

Unlike wastewater, most runoff that enters storm drains is untreated and directly flows into creeks, rivers and ultimately to the Bay. Triclosan may be transported into the stormwater system through commercial or residential washing of equipment outdoors with antibacterial soaps (e.g., washing a vehicle or restaurant mats with triclosan-containing products).

# 3. *Impacts to Aquatic Ecosystems*

## 3.1 Aquatic Toxicity and Bioaccumulation

While our current understanding of triclosan's environmental effects is limited, there is evidence that triclosan is acutely and chronically toxic to aquatic organisms.[10,11, 12] Research has shown that the presence of triclosan may influence both the structure and the function of algal communities in stream

[6] Kolpin, Dana et al. (2002) Pharmaceuticals, hormones and other organic wastewater contaminants in U.S. Streams, 1999-2000: A National Reconnaissance, *Environmental Science and Technology* v. 36: 1202-1211.
[7] Oros, Daniel and David, Nicole (2002). Identification and Evaluation of Unidentified Organic Contaminants in the San Francisco Estuary, *San Francisco Estuary Regional Monitoring Program for Trace Substances*, SFEI Contribution 45.
[8] Samsøe-Petersen, L., M. Winther-Nielsen, and T. Madsen, Danish EPA, "*Fate and Effects of Triclosan*," September 2003.
[9] H. Singer, S. Muller, C. Tixier and L. Pillonel, *Environ. Sci. Technol*. 2002, 36, 4998-5004
[10] Adolfsson-Erici, M.; Pettersson, M.; Parkkonen, J.; Sturve, J. *Organohalogen Compd*. 2000, 45, 83-86.
[11] Offhaus, K.; Klingl, H.; Scherb, K.; Wachs, B. 1978.
[12] Orvos, D. R.; Versteeg, D. J.; Inauen, J.; Dapdevielle, M.; Rothenstein, A.; Cunningham, V. *Environ. Toxicol. Chem.* 2002, 21, 1338-1349.

ecosystems receiving treated wastewater effluent.[13] These changes could result in shifts in both the nutrient processing capacity and the natural food web structure of these streams.

In addition to aquatic toxicity, research suggests that triclosan bioaccumulates in fish tissue. According to a literature review by the Danish Environmental Protection Agency, triclosan bioaccumulates in fish, with bioaccumulation factors of 3,700 to 8,400.[14] This means that the concentrations found in fish are thousands of times higher than what is found in the water column.

Furthermore, at least one transformation product, methyl triclosan (see further discussion in Section 3.2), is relatively stable in the environment, making it also available for bioaccumulation.
Once methylated, the lipophilicity of triclosan increases, meaning that it will be more likely to bioaccumulate in fatty tissue and is not likely to photodegrade.[15] In a Swiss study, the lipid-based concentrations of methyl triclosan observed in fish were considerably higher than the concentrations in lake water, suggesting significant bioaccumulation of the compound. For aquatic organisms, the potential uptake mechanisms of lipophilic contaminants are direct uptake from water through exposed surfaces, mainly gills (bioconcentration), and uptake through the consumption of food (biomagnification).[16]

## 3.2 Environmental Transformation into Other Toxic Compounds

Once triclosan is released into the environment, the compound may undergo photodegradation or biodegradation. Several studies have shown that triclosan can be transformed into other potentially toxic compounds, including methyl triclosan, dioxins, chloroform, and other chlorinated compounds. Triclosan is likely being methylated in wastewater treatment plants, where there is a high density of microorganisms. Both triclosan and its transformation product, methyl triclosan, are found in wastewater treatment plants effluent and both have recently been detected in Swiss receiving waters.[17]

### Degradation By-Products

Under certain circumstances, triclosan can rapidly photodegrade into dioxins and other chlorinated priority pollutants.

According to a University of Minnesota study, triclosan rapidly photodegrades by direct photolysis and both 2,8-dichlorodibenzo-*p*-dioxin (2,8-DCDD) and 2,4-dichlorophenol (2,4-DCP) are produced.[18]

---

[13] B.A. Wilson, V.H Smith, F. de Noyelles Jr. C.K. Larive, *Effects of three pharmaceutical and personal care products on natural freshwater algal assemblages*, Environ.Sci. Technol. **2003**.
[14] L. Samsoe-Petersen, M. Winther-Nielsen, and T. Madsen, Danish EPA, "*Fate and Effects of Triclosan*," September 2003.
[15] Lindstrom, A.; Buerge, I. J.; Poiger, T.; Bergqvist, P.-A.; Muller, M.D.; Buser, H.-R. *Occurrence and Environmental Behavior of the Bactericide Triclosan and Its Methyl Derivative in Surface Waters and in Wastewater Environ. Sci. Technol*. 2002. 36, 2322-2329
[16] Balmer. M.; Poiger, T.; Droz. C.; Romanin. K.; Bergqvist, P.; Muller. M.; Buser. R.; *Occurance of methyl triclosan, a transformation product of the batericide Triclosan, in fish from various lakes in Switzerland. Environ. Sci. Technol*. 2004, 38, 390-395.
[17] Lindstrom, A.; Buerge, I. J.; Poiger, T.; Bergqvist, P.-A.; Muller, M.D.; Buser, H.-R. *Occurrence and Environmental Behavior of the Bactericide Triclosan and Its Methyl Derivative in Surface Waters and in Wastewater. Environ. Sci. Technol*. 2002. 36, 2322-2329.

[18] D.E. Latch, J.L. Packer, B.L. Stender, J.VanOverbeke, W.A. Arnold, K.McNeill. *Aqueous Photochemistry of Triclosan: Formation of 2,4-Dichlorophenol, 2,8-Dichlorodibenzo-p-Dioxin, and Oligomerization Products. Environ. Sci. Technol.* 2005. 24, 517-525.

2,8-DCDD is at least 150,000 times less toxic than the most harmful forms of dioxins, but repeated exposure to chlorine in water treatment facilities can chlorinate triclosan. Chlorinated triclosan is discharged from a wastewater treatment plant, and sunlight can convert it into more toxic dioxins.[19] Even low levels of dioxin congeners are of concern because dioxins readily accumulate in organisms and become more concentrated in tissues through biomagnification.

Research also indicates triclosan reacts with free chlorine to produce a number of breakdown products, including 2,4 dichlorophenol (2,4-DCP). The formation of 2,4-DCP is of a concern because it's an U.S. EPA priority pollutant, and is considered toxic to fish and other water dwelling organisms.[20, 21] 2,4-DCP is used in the manufacture of certain pesticides, antiseptics, and disinfectants. It is a degradation intermediate of the pesticide 2,4-D and various other pesticides. In addition, in the presence of sunlight, the 2,4-DCP further breaks down and may produce more highly chlorinated dioxins than 2,8-DCDD that may be far more toxic.[22]

Recent research from the Virginia Polytechnic Institute and State University also shows that triclosan in household dishwashing soaps reacts with chlorinated water to produce significant quantities of chloroform, a probable human carcinogen.[23]

### 3.3 Bacterial Resistance to Antibiotics

Triclosan may encourage the development of antibiotic resistance in pathogenic bacteria. Scientists worldwide are concerned that the overuse and misuse of antibiotics and antimicrobials may lead to an increased resistance among bacteria.

An article published by the American Medical Association indicates the level of concern in the medical community: [24]

> *"Despite their recent proliferation in consumer products, the use of antibacterial agents such as triclosan in consumer products has not been studied extensively. No data exist to support their efficacy when used in such products or any need for them, but increasing data now suggest growing acquired resistance to these commonly used antimicrobial agents."*

> *"The use of common antimicrobials for which acquired resistance has been demonstrated in bacteria as ingredients in consumer products should be discontinued, unless data emerge to conclusively show that such resistance has no impact on public health and that such products are effective at preventing infection."*

Unlike bleach and soap that destroy and dislodge bacteria microbes, triclosan works by interfering with a specific bacterial enzyme. Non-specific antiseptics, such as alcohol, merely break open the cell and, therefore, are not the type of chemical which bacteria could develop resistance. On the other hand, triclosans mode of action is different from alcohols and peroxide. Triclosan is fat-soluble and easily

[19] K. McNeil, Quote, "Sunlight Converts Common Antibacterial to Dioxin", Ascribe Newswire, April 14, 2003
[20] D.E. Latch, J. Packer, B. Stender, J. Van Overbeke, W. Arnold, and K. McNeill, *Aqueous Photochemistry of Triclosan: formation of 2,4-Dichlorophenol, 2,8-Dichlorodibenzo-p-Dioxin, and Oligomerization Products, Environ. Toxicol. Chem*, Vol. 24, No. 3, pp. 517-525, 2005.
[21] EPA, Office of Water. Water Quality Standards Database Ambient Water Quality Criteria for 2,4-dichlorophenol. EPA 440/5-80-042, October 1980.
[22] K. McNeill, http://pubs.acs.org/subscribe/journals/esthag-w/2005/apr/science/kb_chlorine.html
[22] K.L. Rule, V.R. Ebbett, P.J. Vikesland. *Formation of Chloroform and Chlorinated Organics by Free-Chlorine-Mediated Oxidation of Triclosan. Environ. Sci. Technol*. 2005. 39, 3176 - 3185.
[24] http://www.ama-assn.org/ama/pub/article/2036-2913.html

penetrates the bacterial cell wall. And once inside the cell it attacks an enzyme that is used to produce fatty acids that are vital to cell function.[25,26] This type of mode-of-action could ultimately lead to the development of antibiotic resistance. Through continual use of triclosan, non-resistant bacterial strains would be killed, leaving only the bacteria whose enzyme system has evolved to resist the presence of triclosan. Some microbiologists fear that the commercial and personal overuse of triclosan could reduce effectiveness of currently useful antibiotics. For instance, an antibiotic used to treat tuberculosis targets the same enzyme system.[27]

## *4. Alternatives to Antibacterial Agents Are Readily Available*

According to the Centers for Disease Control and Prevention (CDC), vigorous hand washing in warm water with plain soap for at least 10 seconds is sufficient to fight germs in most cases, even for healthcare workers.[28] For extra assurance, use of an alcohol- or peroxide-based hand sanitizer product is a good option.

> *"The use of these products have never been shown to be superior, to my knowledge, to regular soap and water" says Dr. Tamar Barlan, director of the Center for Science in the Public Interest's project on antibiotic resistance.*[29]

As a result of data developed in Europe on triclosan, several major United Kingdom supermarkets banned the sale of consumer products containing the antibacterial agent in late 2003.[30]

Regarding the use of cutting boards, the following quote from the Mayo Clinic web site indicates that cutting boards impregnated with triclosan are ineffectual:

> *"There's no evidence that cutting boards containing triclosan, an antibacterial agent, prevent the spread of food-borne infections. These boards also may give a false sense of security and cause you to relax other efforts to keep the board clean. In addition, triclosan-treated boards don't kill germs. Antibacterial compounds only slow reproduction of microorganisms. Germs will die, but slowly enough to still contaminate other food or hands that come into contact with the board"* [31]

For alternatives to triclosan-containing cutting boards, the Center for Food Safety and Applied Nutrition recommends that households use a two cutting board system. Use one board for cutting foods that will be cooked (e.g., raw meats, poultry, fish, vegetables) and one for ready-to-eat foods (e.g., breads, fresh fruits).

When selecting products such as hand soap, toothpaste, and deodorants, read the label. If the product states "antibacterial" locate the active ingredients list to see if the product contains triclosan or other anti-bacterial agents. Consumers may opt to purchase products that either are not labeled "antibacterial" or contain alcohol or hydrogen peroxide as the antibacterial agent.

---

[25] McMurray, L. M., Oethinger, M, Levy, S. B., "*Triclosan targets lipid synthesis*", *Nature* (1998) 394, 531-32.
[26] Levy, C. W., Roujeinikovai, A., Sedelnikova, S., Baker, P. J., Stuitje, A. R., Slabas, A. R., Rice, D., & Rafferty, J. B., "*Molecular Basis of Triclosan Activity*", *Nature (1999)*, 398, 383-384.
[27] http://www.sciencenews.org/20000527/fob4.asp
[28] http://www.nurseweek.com/features/98-10/soap.html
[29] http://www.environmentalobservatory.org/News/news.cfm?News_ID=1973
[30] Edwards, Rob. "Supermarkets to ban toxic detergents", Sunday Herald. http://ww1.sundayherald.com/37782
[31] http://www.mayoclinic.com/invoke.cfm?objectid=D542B4F4-649E-4014-B0444D9488F33C12

## *5. Next Steps*

The SCBWMI Emerging Contaminants Workgroup proposes to initiate a unified regional approach to reduce the use of triclosan in the Bay Area. Below are the suggested next steps.

1. Present this information to other regional and state agencies, including but not limited to:
    - Santa Clara County Medical Association
    - Bay Area Pollution Prevention Group and their member POTWs
    - BACWA/BASMAA Media Relations Group
    - Tri-TAC

2. Present this information to local environmental and health groups and request their support via public outreach campaigns and information to their members. Examples include:
    - Clean Water Action
    - Silicon Valley Toxics Coalition
    - Sierra Club
    - Communities for a Better Environment
    - Surfriders
    - Baykeeper

3. Coordinate with these agencies and groups to develop a public factsheet as well as concise messages that resonate with the public and specific audiences. Possible messages include:
    - Antibacterial products are found in San Francisco Bay.
    - The use of antibacterial products may provide a false sense of security and lead to inadequate hand-washing practices.
    - Alternatives include washing hands with soap and water and using alcohol or peroxide based hand gel sanitizing agents for extra assurance.
    - Minimize use of antibacterial cleaning and personal care products.
    - Avoid antibacterial cutting boards. Use two cutting boards, one for foods to be cooked, and one for ready-to-eat foods (colored boards are available to facilitate instant recognition).

4. Continue to follow scientific literature for additional information regarding environmental fate of antibacterial agents and their by-products.

5. Consider developing State legislation to limit the use of antibacterial agents in consumer products. Concurrently, review opportunities to develop more generic legislation that would address a broader range emerging watershed contaminants.

6. Review opportunities to include messages from other water quality outreach efforts to specific audiences. Such audiences might include:
    - Primary purchasing agents in households and commercial institutions
    - Purchasing departments of public institutions
    - Health care and veterinary professionals
    - Parents and teachers
    - Manufacturers and distributors

## 6. Glossary

**ACUTE TOXICITY-** adverse health effects from a single dose or exposure to a toxic chemical or other toxic substance

**ANTIBACTERIAL-** a product that kills or inhibits the growth of bacteria, generally in foods, inanimate surfaces, or hands; EPA considers that "antibacterial" should only apply to products designed to control human pathogenic microorganisms

**ANTIBIOTIC-** a class of natural and synthetic compounds that are capable of inhibiting the growth of or destroying bacteria and other microorganisms

**ANTIMICROBIAL AGENT-** chemicals used to kill or inhibit the growth of microorganisms whether bacteria, viruses, or fungi. EPA considers that "antimicrobial" should be associated with the protection of articles (e.g., tents)

**ANTISEPTIC-** a product generally used on skin to prevent infection and decay by inhibiting the growth of microorganisms

**BIOACCUMULATE-** an increase in the concentration of a chemical in specific organs or tissues at a level higher than would normally be expected

**BIOCONCENTRATION-** the accumulation of a chemical in tissues of a fish or other organism to levels greater than that in the surrounding environment

**BIOMAGNIFICATION-** a progressive build up of persistent substances by successive trophic levels, meaning that it relates to the concentration ratio in a tissue of a predator organism as compared to that in its prey

**BREAK-DOWN DEGRADATION/BY-PRODUCTS-** substances or chemicals left behind after the original substance undergoes some process, such as digestion or photodegradation

**CHRONIC TOXICITY-** adverse health effects from repeated doses of a toxic chemical or other toxic substance over a relatively prolonged period of time, generally greater than one year

**INERT INGREDIENTS-** compounds that are stable and unreactive under specified conditions

**LIPIDS-** any of a group of organic compounds that generally contain fatty acids and are water insoluble

**METABOLITES-** a substance that takes part in the process of metabolism, which involves the breakdown of complex organic constituents of the body with the liberation of energy for use in bodily functioning

**METHYLATION-** modification of a molecule by the addition of a methyl group

**PHOTODEGRADATION-** the process of decaying or breaking down a substance using sunlight or other radiant energy

## 7. Acknowledgements

The SCBWMI acknowledges the following members of the Emerging Contaminants workgroup in conducting the research and preparing this white paper.

Jessie Denver, City of San Jose
Stephanie Hughes, RMC Water & Environment
Kristy McCumby Hyland, City of Sunnyvale
Karin Didriksen North, City of Palo Alto
Pascal Rubineau, City of San Jose
Luisa Valiela, U.S. EPA
Andria Ventura, Clean Water Action

## 8. Information/ References

Adolfsson-Erici, M. Patterson et al. (2000) Triclosan, a commonly used bactericide found in human milk and in the aquatic environment, in *Abstracts of Dioxin, 2000, 20th International Symposium on Halogenated Environmental Organic Pollutants and POP's: Monterey, Ca.* , v. 48, page 83.

Allard, A S; Remberger, M; Neilson, A H (1987) "Bacterial O-methylation of halogen-substituted phenols," *Appl. Environ. Microbiol*. 53(4), 839-845.

American Medical Association Use of Antimicrobials in Consumer Products, Report 2 of the Council on Scientific Affairs, www.ama-assn.org/ama/pub/article/2036-2913.html.

Balmer, M. E.; Poiger, T.; Droz, C.; Romanin, K.; Bergqvist, P.-A.; Muller, M. D.; Buser, H.-R. (2004) "Occurrence of Methyl Triclosan, a Transformation Product of the Bactericide Triclosan, in Fish from Various Lakes in Switzerland," *Environ. Sci. Technol. 38*(2): 390-395.

Bester, K. (2003) "Triclosan in a sewage treatment process—balances and monitoring data**,"** *Water Research,* 37(16): 3891-3896.

Chuanchuen, Rungtip; Karkhoff-Schweizer, RoxAnn R; Schweizer, Herbert P "High-level triclosan resistance in Pseudomonas aeruginosa is solely a result of efflux," *American Journal of Infection Control* 2003, *31*(2): 124-127.

Crawford, Lester M., Jr. (2002) The Soap and Detergent Association: Remarks by, U.S. Food and Drug Administration, www.fda.gov/oc/speeches/2002/sda1002.html

"Disinfectants in consumer products", advisory report, February 16, 2001, Gezondheidsraad Health Council of the Netherlands, To the Minister of Health, Welfare and Sport, The Hague.

Erickson, Britt (2002) Methyl Triclosan found in Swiss Lakes, *Environmental Science and Technology* v. 36, No 11 228A-230A.

Foran CM, Bennett ER, Benson WH. (2000) "Developmental evaluation of a potential non-steroidal estrogen: triclosan," Marine Environ. Res. 50, 153-6.

Hovander, L. Malmberg et al. (2002) Identification of hydroxylated PCB metabolites and other phenolic halogenated pollutants in human and blood plasma, *Archives of Environmental Contamination and Toxicology*, v. 42, p. 105-117.

Hundt, K; Martin, D; Hammer, E; Jonas, U; Kindermann, M K; Schauer, F (2000) "Transformation of triclosan by Trametes versicolor and Pycnoporus cinnabarinus," Appl. Environ. Microbiol., 66(9), 4157-4160.

Kanetoshi, A; Ogawa, H; Katsura, E; Miura, HKT (1988) "Formation of polychlorinated dibenzo-p-dioxin from 2,4,4'-trichloro-2'-hydroxydiphenyl ether (Irgasan® DP300) and its chlorinated derivatives by exposure to sunlight," J. Chromatogr. A, 454, 145-155.

Kanetoshi, A., Katsura, E., Ogawa, H., Ohyama, T., Kaneshima, H., and Miura, T. (1992) "Acute toxicity, percutaneous absorption and effects on hepatic mixed function oxidase activities of 2,4,4'-trichloro-2'-hydroxydiphenyl ether (Irgasan DP300) and its chlorinated derivatives," Arch. Environ. Contam. Toxicol. 23(1), 91-8.

Kolpin, Dana et al. (2002) Pharmaceuticals, hormones and other organic wastewater contaminants in U.S. Streams, 1999-2000: A National Reconnaissance, *Environmental Science and Technology* v. 36: 1202-1211.

Latch, D. E.; Packer, J. L; Arnold, W. A.; McNeill, K. (2003) "Photochemical Conversion of Triclosan to 2,8-Dichlorodibenzo-p-dioxin," *J. Photochem. Photobiol. A. 158:* 63-66.

Levy, C. W.; Roujeinikovai, A.; Sedelnikova, S.; Baker, P. J.; Stuitje, A. R.; Slabas, A. R.; Rice, D.; & Rafferty, J. B. (1999). "Molecular Basis of Triclosan Activity", *Nature*, **398**, 383-384.

Lindstrom, A.; Buerge, I. J.; Poiger, T.; Bergqvist, P.-A.; Muller, M. D.; Buser, H.-R. (2002) "Occurrence and Environmental Behavior of the Bactericide Triclosan and Its Methyl Derivative in Surface Waters and in Wastewater," *Environ. Sci. Technol. 36*(11): 2322-2329.

Lopez-Avila, V. and Hites, R.A. (1980) "Organic compounds in an industrial wastewater: their transport into sediments," Environ. Sci. Technol. 14, 1382-1390.

McMurry, L.M. et al. (1998) Triclosan targets lipid synthesis, *Nature* v. 394, no. 6, p. 531-532.

Meade, M.J. et al (2001) Soil bacteria *Pseudomonas putida* and *Alcaligenes xylosoxidans* subsp. *Denitrificans* inactivate triclosan in liquid and solid substrates, *FEMS Microbiology Letters*, v. 204, p. 45-48.

Neilson, A.H., A. Allard, P-A. Hynning, M. Remberger and L. Landner (1983) "Bacterial methylation of chlorinated phenols and guaiacols; formation of veratroles from guaiacols and high-molecular weight chlorinated lignin," *Appl. Environ. Microbiol*. 45, 774-783.

Oros, Daniel and David, Nicole (2002). Identification and Evaluation of Unidentified Organic Contaminants in the San Francisco Estuary, *San Francisco Estuary Regional Monitoring Program for Trace Substances*, SFEI Contribution 45.

Samsøe-Petersen, L., M. Winther-Nielsen, and T. Madsen, "*Fate and Effects of Triclosan*," Environmental Project No. 861. Danish Environmental Protection Agency. 2003

Singer, H.; Muller, S.; Tixier, C.; Pillonel, L. (2002) "Triclosan: Occurrence and Fate of a Widely Used Biocide in the Aquatic Environment: Field Measurements in Wastewater Treatment Plants, Surface Waters, and Lake Sediments," *Environ. Sci. Technol. 36*(23): 4998-5004.

Voets, J P; Pipyn, P; Van Lancker, P; Verstraete, W (1976) "Degradation of microbicides under different environmental conditions," J. Appl. Bacteriol., 40(1), 67-72.

Wilkison, Donald, Armstrong, Daniel, and Blevins, Dale (2001) Effects of Wastewater and Combined Sewer Overflows on Water Quality in the Blue River Basin, Kansas City, Missouri and Kansas, July 1998- October 2000, www.marc.org/current/blueriver.pdf.

Wilson, B. A; Smith, V. H; deNoyelles, F.; Jr; Larive, Cynthia K (2003) "Effects of three pharmaceutical and personal care products on natural freshwater algal assemblages," *Environmental Science & Technology, 37*(9):1713-1719.