12-1-2016

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Published version. *Antimicrobial Agents and Chemotherapy*, Vol. 60, No. 12 (December 2016): 7015-7016. DOI.

AMERICAN SOCIETY FOR MICROBIOLOGY | Antimicrobial Agents and Chemotherapy

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COMMENTARY

Triclosan: an Instructive Tale

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The Food and Drug Administration (FDA) recently released a final rule to ban triclosan and 18 other antimicrobial chemicals from soaps. We applaud this rule specifically because of the associated risks that triclosan poses to the spread of antibiotic resistance throughout the environment. This persistent chemical constantly stresses bacteria to adapt, and behavior that promotes antibiotic resistance needs to be stopped immediately when the benefits are null.

Global projections estimate that by 2050, one person will die every 3 s if nothing is done to address antibiotic resistance, making it imperative to examine and address all contributors to this very serious health problem. One year ago, the Food and Drug Administration (FDA) asked soap companies to provide evidence that triclosan (TCS)-containing soap was more effective than regular soap, i.e., soap without added antimicrobial agents. If no added benefit was demonstrated, TCS would need to be removed from soaps.

Fortunately, a plethora of research offered valuable insight into the effectiveness of this practice. In summary, peer-reviewed studies revealed no added benefit unless the soap was administered in a high dose and with high frequency. Thus, on 9 September 2016, the FDA enacted a ban on triclosan and 18 other biocidal chemicals that were deemed nonbeneficial to household wash products.

Though late in coming, we applaud this action by the FDA. It is unfortunate that these chemicals have become common household products and have ended up as ubiquitous environmental contaminants. A certain amount of damage has already been done. The ban is a move to correct this, but persistence of these biocides in the environment remains an issue. Eliminating TCS from soaps has few drawbacks but potentially major benefits for mitigating the spread of antibiotic resistance.

Triclosan was originally thought to be a broad-spectrum antimicrobial with no specific target. However, nearly 2 decades ago, it was discovered to have specific targets in bacteria, indicating the potential for bacteria to adapt (1). Resistance to triclosan via multiple mechanisms, including efflux pumps, which are a major concern, as they confer resistance to multiple antibiotics, has since been identified (2). Thus, bacteria exposed to triclosan may become resistant to triclosan itself and also exhibit cross-resistance to antibiotics, as shown in laboratory-based experiments (2). Although triclosan escalated in environmental sediments, waters, and breast milk, short-term examinations of household environments failed to demonstrate a solid link between biocide use and the observed escalation of antibiotic resistance. Concern with triclosan though is not related to the immediate effects on our biomes following use of biocide-containing wash products but rather to the impact of widespread dissemination of these biocides in the environmental resistome and, consequently, the global spread of antibiotic resistance.

Triclosan is now ubiquitous in our environment, including in rivers, lakes, sediment, and soil, because after its use in households, triclosan travels down the drain into our cities' wastewater treatment plants. As an antimicrobial, triclosan is designed to resist the degradation that typically occurs during wastewater treatment. We now know that the majority of triclosan binds to the biosolids that go through wastewater treatment processes, such as anaerobic digestion, a process that is rich in bacteria, warm in temperature, and abundant in chemicals and provides the perfect breeding ground for the exchange of genetic material and promotion of antibiotic resistance. Not surprisingly, triclosan was found to select for a gene that confers multidrug resistance at environmentally relevant levels in anaerobic digesters (3). Of more direct concern, digesters exposed to triclosan are more tolerant of ciprofloxacin than digesters not exposed to it (4), thus highlighting the major concern with widespread triclosan usage: exposure to TCS will lead to cross-resistance to clinically relevant drugs. These recent studies have made a stronger case for the pressures exerted by biocides on the microbial flora found in our cities' wastewater treatment plants, which treat hospital and household wastewater. In spite of this evidence, triclosan and other questionable biocides continue to be incorporated into hundreds of household products. Indeed, a national survey of wastewater biosolids found that triclosan is the second most abundant chemical; it is more abundant than any other pharmaceutical, antibiotic, personal care product, surfactant, or hormone (5). In fact, triclosan is often detected at multiple orders of magnitude higher than the concentrations of antibiotics. Nearly half of the biosolids produced by anaerobic digesters are land applied as soil conditioners, bringing with them over 50 tons of triclosan to soils each year (5). The only chemical found in higher abundance was the antimicrobial triclocarban, used in bar soaps and subject to this ban.

The newly enacted ban on triclosan and triclocarban handwashes may help to slow residue accumulation, but decades of triclosan and triclocarban usage have left us with multiple contaminated environments, which will likely exert negative effects for years to come. Moreover, the continued use of triclosan in toothpaste and other products will likely add chemical pressure to

Accepted manuscript posted online 10 October 2016

Citation McNamara PJ, Levy SB. 2016. Triclosan: an instructive tale. Antimicrob Agents Chemother 60:7015–7016. doi:10.1128/AAC.02105-16.

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environmental bacteria that will lead to the selection of more antibiotic-resistant bacteria.

Moving forward, caution should be exercised when considering what chemicals, if any, are placed into everyday consumer products. Foreseeing the impending ban and noting the mounting scientific inquiry/evidence, coupled with consumer concerns and pressure on multiple fronts (i.e., resistance and endocrine dysfunction), many companies began withdrawing the objectionable compounds. These compounds were, however, often replaced with another chemical—one of the many quaternary ammonium compounds. These substitutes have received less scrutiny than triclosan but nonetheless still have a documented history of promoting cross-resistance to antibiotics (6). Another possibility that companies might pursue is to slightly chemically modify and remarket triclosan with the claim that we have no insight on this new chemical. This claim should be met with strong criticism. We are of the opinion that regular soap is effective and that no biocide enhancements are needed.

Ethanol-based sanitizers are used more prevalently in hospitals because they have proven clinical efficacy and do not pose the risk of promoting antibiotic resistance (note that, apparently, methicillin-resistant *Staphylococcus aureus* patients are the cause of much TCS in hospital wastewaters). Any new chemical should demonstrate documented benefits, and "safe" alternatives should be demonstrated to be safe. Behavior that promotes antibiotic resistance needs to be stopped immediately when the benefits are null.

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