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Study on detection methods for triclocarban

Liyun Yuan, Xiaodong Dong*

College of Medicine, Hebei University, Baoding 071000, China

*Corresponding Author: xddong@hbu.edu.cn

Abstract

Triclocarban (TCC) is used in a wide range of household and personal care products, such as soaps, shampoos, creams, mouthwash, and toothpaste. However, TCC is found to have harmful effects on humans and other animals because of its increasing methemoglobinemia. TCC exposure enhances the estradiol-dependent or testosterone-dependent activation of the estrogen receptor-responsive and the androgen receptor-responsive gene expression in human ovary cells. The potential risk to the environment and human health generated by TCC is currently drawing considerable attention worldwide. Therefore, the development of rapid, sensitive, and reliable analytical methods is necessary to determine the presence of TCC in environmental samples for safety evaluation. In this article the studies of detection methods for TCC in recent years are reviewed.

Keywords: Triclocarban; TCC; determination; detection; sensor.

1. Introduction

Triclocarban (3,4,4-trichlorocarbanilide, TCC) is a hydrophobic molecule and a synthetic antibacterial and antifungal agent, has been broadly used in a wide range of personal care, household and industrial products, such as toothpastes, bar and liquid soaps, deodorants, cosmetics, skin care lotions, sponges and cutting boards [1-3]. TCC has a number of properties suggestive of potential adverse environmental behavior. As a nonagricultural pesticide released into wastewater, TCC is toxic to humans and other animals. It triggers methemoglobinemia and causes a reduction in the rate at which exposed mammals conceive, in the number of offspring born, as well as in the survival rate and body weight of the young. Its polychlorinated aromatic structure suggests a potentially significant resistance to biotransformation and biodegradation. Today, the potential risks associated with the release of TCC into the environment and its effects on human health have attracted increased attention worldwide [4-6]. Therefore, a sensitive and efficient method for determining TCC in environmental samples must be developed. In this paper, the attributes of different analytical technique for the determination of TCC in recent years are reviewed.

2. Analytical Methods

2.1. HPLC method. High-performance liquid chromatography (HPLC) is a powerful tool that enables the separation of complex mixtures into individual components, and is a highly sensitive and reproducible analytical technique. In recent years, HPLC has been combined with many sensitive detection techniques and has experienced continuous improvement of stationary phases, which have improved its sensitivity and specificity. HPLC is currently widely used for the analysis of drugs and dosage forms with respect to quality control, quantitative determination of active ingredients and impurities, monitoring drug blood concentration in patients, and bioequivalence assessment [7,8].

Miao *et al.* [9] developed a specific, sensitive, and reliable analytical method involving homogenate extraction, solid phase extraction (SPE), and detection by HPLC-electrospray ionization tandem mass spectrometry for the determination of TCC in aquatic plants. They examined and optimized the key factors that could affect the extraction and clean-up performance, including the extraction solvent and its volume, the homogenate extraction time, the SPE

cartridge used, and the eluents and their volume. Under optimum conditions, the linearity of the method ranged from 0.2 ng g⁻¹ to 200 ng g⁻¹, with correlation coefficients (r²) >0.999. The limit of detection was 0.05 ng g⁻¹, based on the ratio of the chromatographic signal to baseline noise. Spiked recoveries of TCC in real aquatic plant samples ranged from 91.8% to 106.1%. The matrix effect value was 101.9%, with a relative standard deviation of 5.1%. The proposed method was successfully applied to analyze TCC in aquatic plant samples collected from a natural water environment.

Camino-Sanchez *et al.* [10] developed and validated an accurate and sensitive method for the determination of selected endocrine disrupting chemicals in soil and compost from wastewater treatment plants. Five parabens, six benzophenone-UV filters and the antibacterials triclosan and TCC were selected as target analytes. The parameters for ultrasound-assisted extraction were thoroughly optimized. After extraction, the analytes were detected and quantified using ultra-high performance liquid chromatography tandem mass spectrometry. Ethylparaben and deuterated benzophenone were used as internal standards. The method was validated using matrix-matched calibration and recovery assays with spiked samples. The limits of detection ranged from 0.03 to 0.40 ng g⁻¹ and the limits of quantification from 0.1 to 1.0 ng g⁻¹, while precision in terms of relative standard deviation was between 9% and 21%. Recovery rates ranged from 83% to 107%. The validated method was applied for the study of the behavior of the selected compounds in agricultural soils treated and un-treated with compost from wastewater treatment plants.

2.2. Electrochemical method. Since the early 70s electrochemistry has been used as a powerful analytical technique for monitoring electroactive species in living organisms. It is a promising alternative for the determination of organic molecules in complex matrices, because it delivers lower cost and analysis time, high selectivity, and high sensitivity. [11-13].

Lucio *et al.* [14] presented the first report of TCC electrochemical oxidation aiming at its determination in personal care products and drinking water samples at trace levels, using square wave voltammetry (SWV) direct and adsorptive stripping modes. They evaluated the electrochemical responses of TCC using different voltammetric techniques over a wide pH range on a glassy carbon electrode, demonstrating irreversible and diffusion-controlled processes, and estimated the numbers of protons and electrons associated with the oxidation reactions. The most selective and sensitive response was used for the development of SWV methods, under optimum conditions. A linear response range from (1.8–21) × 10⁻⁹ mol L⁻¹ with a limit of detection of 3.2 × 10⁻¹⁰ mol L⁻¹, 1000 times lower than SWV direct mode, was obtained for SWV adsorptive stripping mode, including the acceptable levels of

repeatability and reproducibility and has been applied to TCC determination in personal care products at levels ranging from 0.21 to 0.49 % m m⁻¹ and drinking water samples, with excellent analytical performance using simple and low cost instrumentation.

Martin *et al.* [15] explored the electrochemical reduction of TCC at a silver cathode as a possible method of remediation. Cyclic voltammograms for the reduction of TCC showed three cathodic peaks at both glassy carbon and silver cathodes in dimethylformamide (DMF) containing 0.05 M tetramethylammonium tetrafluoroborate. In comparison with a glassy carbon electrode, each peak was shifted approximately 30 mV toward more positive values at silver, the respective peak potentials being -1.27, -1.37, and -1.80 V vs. a cadmium amalgam reference electrode. Whereas the two most positive cathodic peaks for reduction of TCC were nearly merged at a typical scan rate of 100 mV s⁻¹, lower scan rates can be employed to increase the separation of these peaks. Three comparable cathodic peaks for TCC were seen for a silver cathode in dimethyl sulfoxide, but only two cathodic peaks were observed in acetonitrile. In a solvent consisting of 10% water–90% DMF, only one cathodic peak, corresponding to the most positive peak in the other solvents, was seen before the onset of electrolytic breakdown of the solvent–electrolyte. Diphenylurea, the product anticipated from complete dechlorination of TCC, exhibited a single cathodic peak at -1.80 V in DMF, with a significantly smaller current than the corresponding peak for reduction of TCC. Preliminary results obtained from controlled-potential (bulk) electrolyses in DMF with a silver gauze cathode indicated that partial dechlorination of TCC does occur over a range of initial concentrations.

3. Conclusions

The widespread use of antimicrobial products containing TCC continuously introduces the molecule into the environment and may adversely affect plants, animals and human health [16-18]. This review has highlighted the significant developments in rapid and alternative techniques for the detection of TCC in recent years. We believe the development of TCC sensors with better sensitivity and specificity, lower cost, simplicity, along with in vivo analytical technique is still the future effort.

Acknowledgments

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