

Triclosan occurrence in European Sewage Treatment Plants and risk assessment for the European rivers

Thomaidi V.S.¹, Matsoukas C.¹, Stasinakis A.S.^{1,*}

¹Department of Environment, University of the Aegean, 81100 Mytilene

*corresponding author: e-mail: astas@env.aegean.gr

Abstract

The purpose of this study was to estimate the environmental risk associated with the existence of triclosan (TCS) released from municipal wastewater in the European rivers. A literature review was held to record the concentration levels of TCS in effluents of European Sewage Treatment Plants (STPs), while toxicity data was collected for aquatic organisms (algae, *Daphnia magna* and fish). Risk assessment was based on both Risk Quotient (RQ) methodology and Monte Carlo simulation. According to the results, TCS monitoring data was available for 349 STPs located in 15 out of the 50 European countries. Its mean concentrations ranged between 2.2 ng L⁻¹ and 47,800 ng L⁻¹. The 95th percentile of RQ was higher than 1 (in algae) for rivers with dilution factors (DFs) equal to or lower than 100, when maximum concentration was used, whereas the 95th percentile of RQ exceeded 1 for rivers with DFs up to 10, in cases where the calculations were based on mean concentration values.

Keywords: micropollutants, wastewater, risk assessment, Monte Carlo simulation, river water.

1. Introduction

Emerging micropollutants (EMPs), such as pharmaceuticals and personal care products, enter the aquatic environment via various routes (Farré et al., 2008). Sewage Treatment Plants (STPs) constitute one of the main pathways, as EMPs present insufficient removal during the wastewater treatment processes (Stasinakis et al., 2013). A commonly detected EMP in STP effluents is the broad-spectrum antimicrobial agent triclosan (TCS), which is widely used in everyday products (Bester, 2003).

In the United States, a discussion among scientists, authorities and agencies concerning the safety of TCS and the need to be regulated, has been in progress during the last decade. The U.S. Environmental Protection Agency (EPA) has regulated TCS as registered pesticide under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) (Halden, 2014ab). By contrast, to the best of our knowledge, such a discussion is not ongoing in Europe among scientists, with the exception of the *Opinion on Triclosan* propounded by the Scientific Committee on Consumer Safety (SCCS) of the European Union (EU), which recommends the prudent use of TCS (SCCS, 2010). This is, maybe, due to the vague information concerning occurrence and monitoring of TCS in Europe, as well as

the disadvantages of the applied risk assessment RQ methodology, which should only be seen as a first attempt to assess the risk associated with the presence of EMPs in the environment.

In this context, the objectives of this study were to: a) present monitoring data of TCS detected in the STP effluents of all European countries, b) present experimental toxicity data of TCS, related to the aquatic organisms algae, *Daphnia magna* and fish, and c) estimate the uncertainty that undergoes the estimation of the RQ, when the aforementioned methodology is applied.

2. Materials and Methods

2.1. Monitoring data collection

An extended literature review was conducted between May and July 2016, to collect the monitoring data of TCS in European STPs' treated wastewater. The review was held for all European countries (totally 50). Data, dated from 2002 to 2015, was retrieved using the Scopus database. The search terms were "triclosan" AND "concentration OR occurrence OR monitoring" AND "wastewater OR effluents OR sewage" AND "the name of the country". The STPs covered in these studies reaches the total number of 349.

2.2. Toxicity data collection

Data reported in the literature on TCS ecotoxicological acute and chronic effects, on different groups of aquatic organisms, was collected from 34 international articles, dated from 1986 to 2016. The search was conducted between July and August 2016, using the Scopus database as the source of publications. The search terms were "triclosan" AND "aquatic toxicity OR EC50 OR LC50 OR NOEC". Experimental effective/lethal concentration at a 50% level (EC50/LC50) and no-observed effect concentration (NOEC) values obtained for algae, *Daphnia magna* and fish were collected.

2.3. Sensitivity analysis

In order to assess the potential risk associated with the presence of TCS in the aquatic environment, the RQ calculations were based on the Measured Environmental Concentration (MEC) of the target compound in treated

wastewater, the Predicted No Effect Concentration (PNEC), for 3 different aquatic organisms; algae, *Daphnia magna* and fish and the dilution factor (DF) the effluents might undergo when released into the rivers (Eq. (1)):

$$RQ = \frac{MEC}{PNEC \times DF} \quad (1)$$

According to the Technical Guidance Document of the European Commission (EU, 2003), PNEC was calculated by dividing the LC50 or EC50 value by an appropriate assessment factor (AF). In this study an AF equal to 100 was used, as other authors have suggested (Wu et al., 2011; Grill et al., 2016 (Eq. (2)):

$$PNEC = \frac{EC50 \text{ or } LC50}{AF} \quad (2)$$

In order to underpin the reliability of the risk assessment methodology, an uncertainty analysis was conducted. Monte Carlo simulation was applied (Wu et al., 2011; Federle et al., 2014) to estimate the uncertainty of the risk posed by TCS to the aquatic organisms.

3. Results and Discussion

3.1. TCS occurrence in European STPs

So far, there is a sufficient number of published articles in scientific journals (68) concerning the presence of TCS in European STPs' treated wastewater. However most of these studies refer to a small number of countries; namely, Spain (27 papers), Greece (12 papers), United Kingdom (8 papers), Germany (6 papers), France (4 papers) and Sweden (3 papers). No data is available for the remaining 35 European countries. The lowest mean concentration value has been measured in Sweden (2.2 ng L⁻¹) and the highest one in Spain (47,800 ng L⁻¹), while the corresponding maximum values were 11 ng L⁻¹ (United Kingdom) and 269,000 ng L⁻¹ (Spain).

3.2. TCS aquatic toxicity data

According to the results of the literature survey, 24 peer-reviewed papers collated data on acute and chronic toxicity values of TCS on the aquatic organisms (algae, *Daphnia magna* and fish). Concerning long-term toxicity, there is scarce data in the literature. As far as short-term toxicity is concerned, the most sensitive aquatic organisms were algae, presenting the lowest EC50/LC50 values. The lowest EC50/LC50 value has been reported for *Pseudokirchneriella subcapitata* (0.53 µg L⁻¹), while the highest for *Nitzschiapalea* (430 µg L⁻¹). Regarding daphnids and fish, EC50/LC50 values range from 52 to 857 µg L⁻¹ and from 45 to 1839 µg L⁻¹, respectively.

3.3. Probabilistic risk assessment

Probabilistic risk assessment revealed that the 95th percentile RQ_{mean} values in effluents for algae, *Daphnia magna* and fish are 64, 0.62 and 0.42, respectively, while in rivers with DFs equal to 2 and 10 the corresponding 95th percentile RQ_{mean} values for algae are still above 1 (32 and 6.4, respectively). No threat seems to occur for the other groups of aquatic organisms in rivers, regardless the DFs' value. Concerning the 95th percentile RQ_{max} values,

algae seem to face a risk even in rivers with high flows. Specifically, the 95th percentile RQ_{max} values for algae are 74, 15 and 1.5 in rivers with DFs equal to 2, 10 and 100, respectively. On the other hand, for *Daphnia magna* and fish the 95th percentile RQ_{max} values are lower than 1 in all rivers, regardless of the DF used.

4. Conclusions

The most threatened aquatic organisms from TCS in European rivers seem to be algae, while the major risk is expected for rivers with DFs lower or equal to 10. Environmental engineers, policy makers and authorities should put a great deal of combined effort to mitigate the concentration levels of TCS in treated wastewater.

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