Trace analysis of isothiazolinones in water samples by large-volume direct injection liquid chromatography tandem mass spectrometry

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Introduction

Isothiazolinones are used as preservatives, biocides and desinfectants in variety of industrial and domestic applications. These include control of microorganism and biofilms in membrane filtration modules, cooling water installations and swimming pools, cleaning agents in, e.g. cosmetics and household products, and slimicides in pulp and paper industry. The purpose of the present study was to develop and optimize an LC–MS/MS method that would enable the determination without any derivatization or preconcentration step of isothiazolinones used in membrane technology for water purification and in household products, at levels relevant for the water cycle. The method was applied to membrane flushings, surface waters and tap water samples, to samples taken from bathing water after domestic use of shampoos, and finally in aqueous dilutions of shampoos in order to determine contents of isothiazolinones in commercial brands of shampoo.

Experimental

Sample procedure

- Filtration: water sample with 0.4 µm filter
- 2 ml large-volume direct on-column loop injection

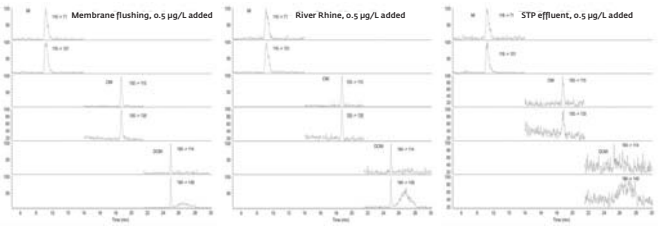
HPLC conditions

- Column: 250 x 4.6 mm Aqua ODS 125A Phenomenex column (5 µm particles)
- Column flow: 1.0 ml/min
- Gradient: linear from 10-90% methanol 90 -10% ultrapure water + 0.1% acetic acid

MS parameters

- Mass spectrometer: Finnigan-MAT TSQ 7000 triple quad
- Ionisation: positive ions by APCI interface, vaporizer 500 °C
- Scantype:MRM two transitions parent ion ⟶ product ion per component
- Collision energy: between 20 and 30 eV (2.0 mTorr Ar)
- Heated capillary: 275 °C

MRM transition chromatogram of three isothiazolinones



Environmental, household samples and commercial shampoos

Sample type	MI	CMI	DCMI
Tap water	< 0.04	< 0.03	< 0.10
River Meuse	< 0.04	< 0.03	< 0.10
River Rhine	< 0.04	< 0.03	< 0.10
STP effluent	< 0.04	< 0.03	< 0.10
Membrane flushing	< 0.04	< 0.03	< 0.10
Bath tub water			
(250 L) after single use of shampoo A	0.11	< 0.03	< 0.10
(250 L) after double use of shampoo B	0.20	< 0.03	< 0.10
Wash basin water (4 L) after single washing with shampoo C	0.37	< 0.03	< 0.10
Commercial Shampoos			
Shampoo D	80	< 3.00	< 12
Shampoo E	90	< 3.00	< 12
Shampoo F	15	130	< 12
Shampoo G	1300	100	< 12
Shampoo H	1200	1700	< 12

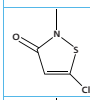
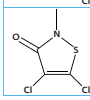
Isothiazolinones in environmental and household samples

The concentrations (µg/L) of the isothiazolinones in STP effluents, aquatic environmentals samples and in tap water were invariably below the LOD's. Obviously due to the instability, these compounds are readily degraded either by microorganism or physical transformation or removal processes, despite the fact that in household water sometimes significant concentrations may be expected and indeed are observed after use of shampoos containing isothiazolinones. Levels in commercial shampoos are analysed after dilution in water, the tabel shows the concentrations in µg/L.

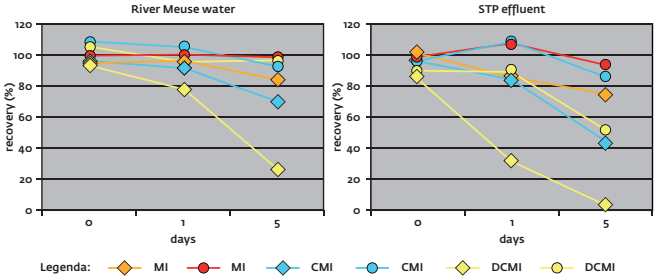
A sensitive and selective analytical method was developed and optimized for the determination of sub-µg/L levels of three isothiazolinones in water samples. The analytical method involves a robust large-volume direct on-column loop injection of 2mL on an Aqua ODS HPLC column and tandem MS detection (HPLC–MS/MS). After filtration, samples are directly injected without further pretreatment. Detection limits of the individual target compounds were between 0.03 and 0.1 µg/L employing Multi-Reaction Monitoring (MRM) mass spectrometry.

Preservation of river water and waste water samples with sodium azide (NaN_3) promotes the stability of the isothiazolinones in solution. In membrane flushings, waste water, surface waters and drinking water, levels of the three isothiazolinones were all below the limit of detection. In effluents of households containing washings from normal shampoo use, isothiazolinones could be detected.

Chemical structures

Structure	Chemical name	Formula	CAS No	log K_{ow}	MRM transitions
	2-methyl-3-isothizolinone (MI)	C_4H_5NOS	2682-20-4	-0.49	116⟶101 116⟶71
	5-chloro-2-methyl-3-isothiazolinone (CMI)	C_4H_4ClNOS	6172-55-4	0.40	150⟶135 150⟶115
	4,5-dichloro-2-methyl-3-isothiazolinone (DCMI)	$C_4H_3Cl_2NOS$	26542-23-4	2.02	184⟶149 184⟶114

Stability in river water and STP effluent



Stability of three isothiazolinones spiked in river water and STP effluent with and without addition of NaN3. Circles, 10 mmol NaN3 added; diamonds, no NaN3 added.

Conclusion

The present study, to our knowledge, is the first employing LC–MS/MS for the analysis of some of the isothiazolinones. Second, it shows that direct on-column injection of relatively large volumes (mL range) of non-pre-treated aqueous samples can be applied when using HPLC stationary phases that are amenable to high water contents (up to 100%) of the sample introduced. The results of the analyses of environmental water samples confirm earlier findings that the levels of the isothiazolinones in the aquatic environment are such that, despite their large volumes of production, they probably do neither pose an environmental nor a human health risk. The analytical method described can be used for checking the presence of preservatives in membrane flushings and in produced water, in line with the European standard EN 12873-4.

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