

# Environmental Concentrations, Fate and Safety of the Organic UV Filter Octyl Methoxycinnamate in Surface Waters

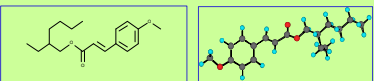
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## ABSTRACT

Octyl Methoxycinnamate (OMC) is an organic UVB filter widely used in a variety of cosmetic products. In common with other cosmetic ingredients, it enters the aquatic environment through the down-the-drain disposal of cosmetic products. In the current study, we measured the concentrations and removal of OMC at trickling filter and activated sludge wastewater treatment plants (WWTPs) in the River Aire Basin in the UK in September, 2000. In addition, the loss of OMC in the river water was measured using semipermeable membrane devices (SPMDs) deployed at various distances downstream from the wastewater treatment plant effluent discharge point. The removal rates and the measured environmental loadings of OMC were used in the GREAT-ER (Geography-Referenced Regional Exposure Assessment Tool for European rivers) model to predict the distribution of concentrations of this chemical in the Aire Basin. The measured WWTP removal rates of OMC were in the range of 90-98% with a further rapid loss in river water ( $k=1.03 \text{ h}^{-1}$ ,  $t_{1/2}=0.67 \text{ h}$ ), as could be expected for a readily biodegradable chemical. Based on the predicted aquatic concentrations of OMC and its ecotoxicological properties, environmental safety can be demonstrated for this compound in the Aire and Calder Basin.

## INTRODUCTION

Octyl Methoxycinnamate (CAS# 5466-77-3) is a UVB filter (290-320 nm) used in a large variety of sunscreens and other cosmetic products. There have been reports indicating the presence of various organic UV filters, including OMC, in lake water, fish and human breast milk (Hany and Nagel, 1995). These findings have raised concerns over the environmental safety of OMC. In response to these concerns, P&G have carried out a study to better understand the fate and safety of OMC in the aquatic environment.



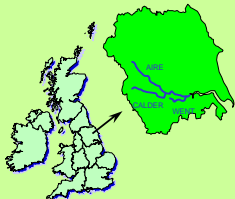
## STUDY OBJECTIVES

1. To investigate the fate of OMC in the aquatic environment, including its removal during wastewater treatment and the loss rate in a natural stream;
2. To model the distribution of OMC concentrations in a river basin using GREAT-ER, a GIS-based regional exposure assessment tool;
3. Using the fate and effect data, to assess the environmental safety of OMC in the Aire and Calder Basin.

## RIVER AIRE BASIN

The Rivers Aire and Calder Basin is situated in Yorkshire, north of England. The River Aire drains the central Pennines and flows south-eastward through West Yorkshire metropolitan area and the Yorkshire coalfield, where it is joined by Calder, its major tributary. These areas are characterized by a high density of population, large number of small tributaries and medium to small size wastewater treatment plants with dilutions factors as low as 2.

## GEOGRAPHIC LOCATION OF THE BASIN



## GREAT-ER

River Aire and three related river basins (Calder, Went and Rother) are modelled in GREAT-ER, the Geography-Referenced Regional Exposure Assessment Tool for European Rivers. GREAT-ER is an environmental model developed by ECETOX (European Centre for Ecotoxicology and Toxicology of Chemicals) and others on behalf of ERASM. GREAT-ER combines environmental models and GIS techniques to predict and visualize the concentration of down-the-drain chemicals in European river basins (Schowanek et al., 2001).

## STUDY SITES

Two wastewater treatment plants were selected for the study. Crofton activated sludge (AS) plant southeast of Wakefield serves the population of about 9,000 people with the wastewater flow of ca 1,400 m<sup>3</sup>/day, and Meltham trickling filter (TF) plant south of Huddersfield serves the population of 8,000 people with the wastewater flow of ca 4,100 m<sup>3</sup>/day. The latter plant operates two consecutive series of trickling filters, i.e. the level of water treatment is equivalent to tertiary treatment. Both plants receive municipal wastewater only. The Meltham plant discharges into Mag Brook, the 3.5-km section of which below the discharge point was used for river water die-away study.

## MAG BROOK



<b>Flow rate</b>	0.13-0.18 m <sup>3</sup> /s (measured)
	0.53 m <sup>3</sup> /s (GREAT-ER, mean)
	0.15 m <sup>3</sup> /s (GREAT-ER, 5 <sup>th</sup> %-ile)
<b>Flow velocity</b>	0.015-0.57 m/s (measured)
	0.22 m/s (GREAT-ER, mean)
<b>Depth</b>	0.05-0.47 m (measured)
	0.55 m (GREAT-ER, mean)

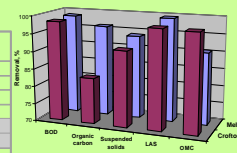
## SAMPLING, SAMPLE PROCESSING AND ANALYTICAL

One-day (24 h) hourly composite samples of influent, primary effluent and final effluent were collected at each wastewater treatment plant. The in-stream die-away rate of OMC was measured by deploying sets of 4 standard commercial semipermeable membrane devices (SPMDs) in Mag Brook 20 m, 750 m, 1500 m and 3500 m downstream from the Meltham WWTP effluent discharge point for a period of 5 weeks. Additionally, a grab-sample die-away study was carried out using a fluorescent die tracer (Rhodamine WT) to estimate the in-stream loss rates of BOD, organic carbon and suspended solids. The water samples, preserved with 3% formalin, were spiked with OMC standard, mixed with ethanol and extracted with hexane. After the solvent exchange to methanol, the extracts were analysed by liquid chromatography - atmospheric pressure chemical ionisation tandem mass spectrometry. SPMDs were extracted using organic solvent dialysis (hexane), and, after volume reduction, spiking and solvent exchange, analysed in the same way as extracts from water.

## RESULTS

### Wastewater treatment removal

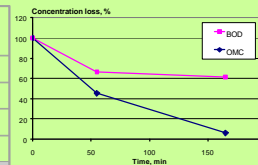
	BOD (mg/l)	Organic carbon (mg/l)	Suspended solids (mg/l)	LAS (mg/l)	OMC (µg/l)
<b>Meltham</b>					
Influent	204	151	228	3.18	3.2
Primary effluent	55.3	33.2	56	2.88	3.0
Final effluent	2.7	5.88	14	0.016	0.3
Primary removal (%)	72.9	78	75.4	9.4	6.3
Total removal (%)	98.7	96.1	93.9	99.5	90.6
<b>Crofton</b>					
Influent	262	126	166	1.71	5.1
Primary effluent	230	142	120	2.4	3.8
Final effluent	4.1	21.4	14	0.029	0.1
Primary removal (%)	12.2	0	27.7	0	25.5
Total removal (%)	98.4	83	91.6	98.3	98



Graphic representation of BOD, organic carbon, suspended solids, LAS and OMC removal rates.

### In-stream removal

	Conductivity		Suspended solids (mg/l)	BOD (mg/l)	Organic carbon (mg/l)	OMC (ng/3 SPMD units)
	µS/cm	Dilution				
Site B (20 m l)	352	Start <sup>1</sup>	9	3.6	9.28	3.3
Site C (0.75 km l)	282	1.25	7	2.4	7.53	1.5
Site D (1.5 km l)	293	1	6	2.2	7.07	0.2
Site E (3.5 km l) <sup>2</sup>	316	1	51	3.1	5.95	0.3
Die away rate B-D (h <sup>-1</sup> )	N/A		0.14	0.16	0.09	1.03

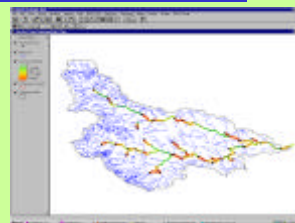


Loss rate of OMC and BOD in water from site B to D.

Notes:

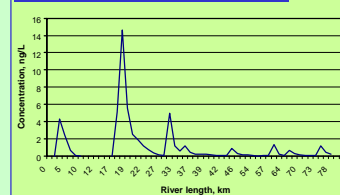
- <sup>1</sup>Conductivity-based dilution factor of Meltham WWTP effluent was 2.94.
- <sup>2</sup>Site E was excluded from the die-away rate calculations as the SPMDs at this site were found to be submerged in sediment at the time of recovery. Elevated suspended solids at site E may reflect disturbance of sediments at the time of sampling.

### GREAT-ER simulation: Aire and Calder Basin



Predicted OMC average concentration in the Aire and Calder Basin (variable default flow rate, measured per capita consumption, WWTP and in-stream removal rates).

### GREAT-ER simulation: concentration profile



Predicted OMC average concentration downstream from Mag Brook (Mag Brook - Holme - Calder - Aire).

### GREAT-ER simulation: calculated concentrations in the Basin

	Concentration (ng/l)	
	C <sub>lim</sub> (mean) ± SD	C <sub>lim</sub> (90%) ± SD
Weighted by volume (loaded stretches only)	1.82 ± 1.42	2.6 ± 2.06
Weighted by length (loaded stretches only)	4.6 ± 0.49	6.40 ± 0.69
Weighted by flow (all stretches)	1.54	12.36
Initial	56.8	



Semipermeable membrane devices (SPMDs)

## REFERENCES

- Hany, J. and Nagel, R., 1995. Detection of sunscreen agents in human breast milk. *Deutsche Lebensmittel-Rundschau*, Vol. 11, pp 341-345.

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## ENVIRONMENTAL SAFETY OF OMC

### Summary of environmental safety characteristics

Organism	Ecotoxicology		Fate	
	Endpoint	Value	Parameter	Value
Daphnia	EC <sub>50</sub>	3.3 mg/l <sup>P</sup>	Water solubility	0.077 mg/l <sup>1</sup>
Daphnia	EC <sub>50</sub>	>1.0 mg/l <sup>2</sup>	Log K <sub>ow</sub>	5.96 <sup>4</sup>
Brachydanio	NOEC	1,000 mg/l <sup>3</sup>	Ready biodeg. (OECD 301F)	Pass <sup>2,3</sup>
Pseudomonas	NOEC	>10,000 mg/l <sup>4</sup>	WWTP Removal (AS)	98% <sup>1</sup>
Scenedesmus	EC <sub>50</sub>	0.4 mg/l <sup>1</sup>	WWTP Removal (TF)	90.6% <sup>1</sup>

<sup>1</sup>P&G (removal rates from the current study), <sup>2</sup>BASF, <sup>3</sup>H&R, <sup>4</sup>Bayer. Note: All toxicity values reflect nominal concentrations except for Scenedesmus which is total measured concentration.

### Environmental risk characterisation

**Predicted no effect concentration (PNEC).** Using an application factor of 1000 (EU TGD), a PNEC of 0.4 µg/l can be derived.

**Environmental safety of OMC in the Aire and Calder Basin.** Depending on the weighing method, the predicted average aquatic concentration of OMC in the Aire and Calder Basin ranged from 1.8 to 4.6 ng/l, resulting in a PEC/PNEC ratio of <=0.01. Under a low flow regime (90<sup>th</sup> percentile), PEC is in the range of 2.6 to 6.4 ng/l with a PEC/PNEC <=0.016. Finally, the predicted average initial concentration of OMC (i.e. average concentration at WWTP discharge sites) is 56.8 ng/l with the resultant PEC/PNEC of 0.14. Environmental safety of OMC in the Aire and Calder Basin can be assumed under all scenarios considered.

**Bioconcentration and sediment compartment.** Due to its highly hydrophobic nature and sorptive potential, bioconcentration as well as the sediment compartment should be considered in the environmental risk assessment of OMC. The ready biodegradation of this chemical and the rapid decline of its concentrations in SPMDs, highly lipophilic passive samplers, over a short river section clearly suggest that OMC is unlikely to accumulate in the tissue of aquatic organisms or in sediments to significant levels. To confirm this, we are planning to run a study on OMC's effects in sediments using a benthic species.

## CONCLUSIONS

**Removal of OMC during wastewater treatment.** The removal of OMC in a trickling filter and activated sludge wastewater treatment plants was 90% and 98%, respectively, in line with expected rates for non-persistent and readily biodegradable chemicals.

**Fate of OMC in the aquatic environment.** The loss rate of OMC in a stream receiving effluent from a wastewater treatment plant was 1.03 h<sup>-1</sup>, with the corresponding half-life of 0.67 hours. This rate is 6-fold higher than the BOD die-away rate, indicating that OMC is short-lived in the aquatic environment.

**Environmental safety of OMC in the Aire and Calder Basin.** The ratio of OMC's predicted environmental concentration and predicted no-effect concentration (PEC/PNEC) was <<1 under all scenarios considered, including the river sites directly below the discharges of wastewater treatment plants.

Schowanek, D. et al., 2001. GREAT-ER: a new tool for management and risk assessment of chemicals in river basins. Contribution to GREAT-ER #10. *Water Science and Technology*, Vol. 43, pp 179-185.

Sabaliunas et al., 2000. Toxicity and genotoxicity of hydrophobic pollutants sampled with semipermeable membrane devices. *Environmental Pollution*, Vol. 109, pp. 251-265.