# Fate of alkylphenolic compounds during activated sludge treatment: Impact of loading and organic composition

Ewan J. McAdam[a], John P. Bagnall[a], Ana Soares[a], Yoong K.K. Koh[b], Tze Y. Chiu[c], Mark D. Scrimshaw[d], John N. Lester[a] and Elise Cartmell[a*]

[a]Centre for Water Science, Cranfield University, Bedfordshire, MK43 0AL, U.K., [b]Public Utilities Board, Technology and Water Quality Office, 40 Scotts Road no. 15-01, Environmental Building, 228231, Singapore, [c]AECOM Design Build, Wentworth Business Park, Tankersley, Barnsley, S75 3DL, U.K. [d]Institute for the Environment, Brunel University, Uxbridge, Middlesex, UB8 3PH, U.K. *Corresponding author: Tel.: +0044 (1234) 758366; Fax.: +0044 (1234) 751671; email: e.cartmell@cranfield.ac.uk

## Supporting information

The supporting information contains three tables (Table S1, S2 and S3) describing the process characteristics of the works, the sanitary determinand concentration data. Settled sewage and final effluent nonylphenolic compound concentrations are provided in Figures S1 and S3 with the correlation of ethoxylate shortening/ carboxylic acid transformation outlined in Figure S2. The nonylphenolic compound biomass sorption coefficients for secondary activated sludge are presented in Table S3.

Supporting information comprises 6 pages, s1-s6.

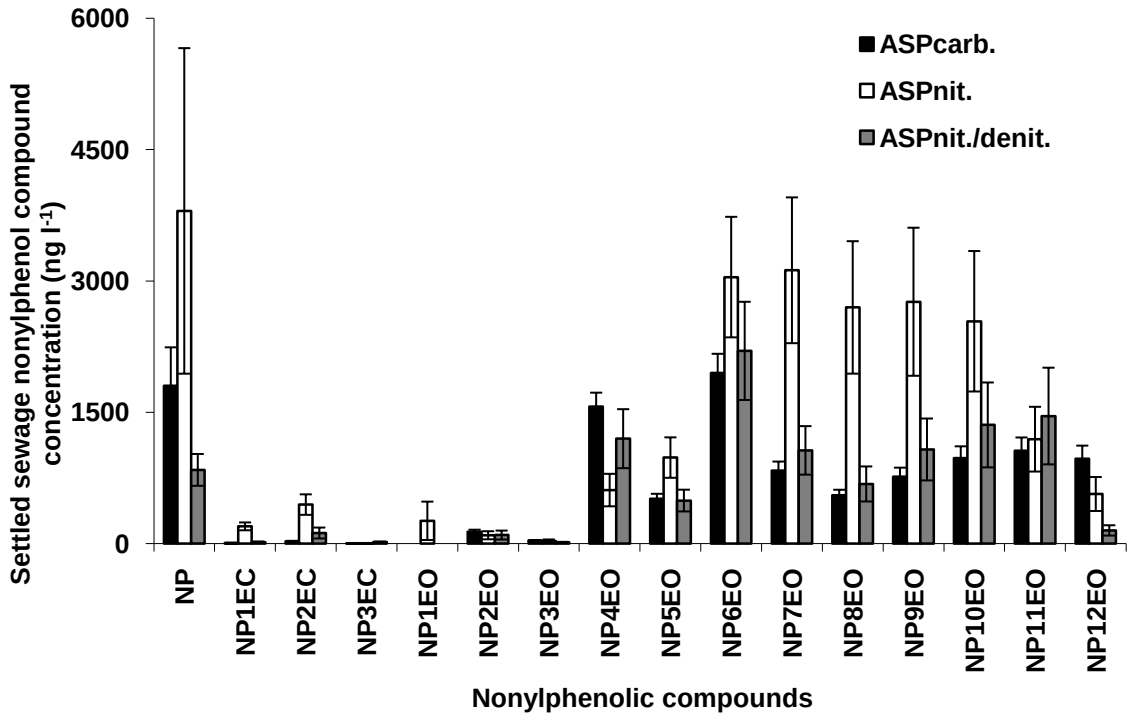


**Figure S1.** *Concentrations of nonylphenolic surfactants and their metabolites in settled sewage (ng $l^{-1}$) for sites: $ASP_{carb}$; $ASP_{nit}$; and $ASP_{nit/denit}$. Averaged data reported (n = 16, standard deviation plotted as error bars).*

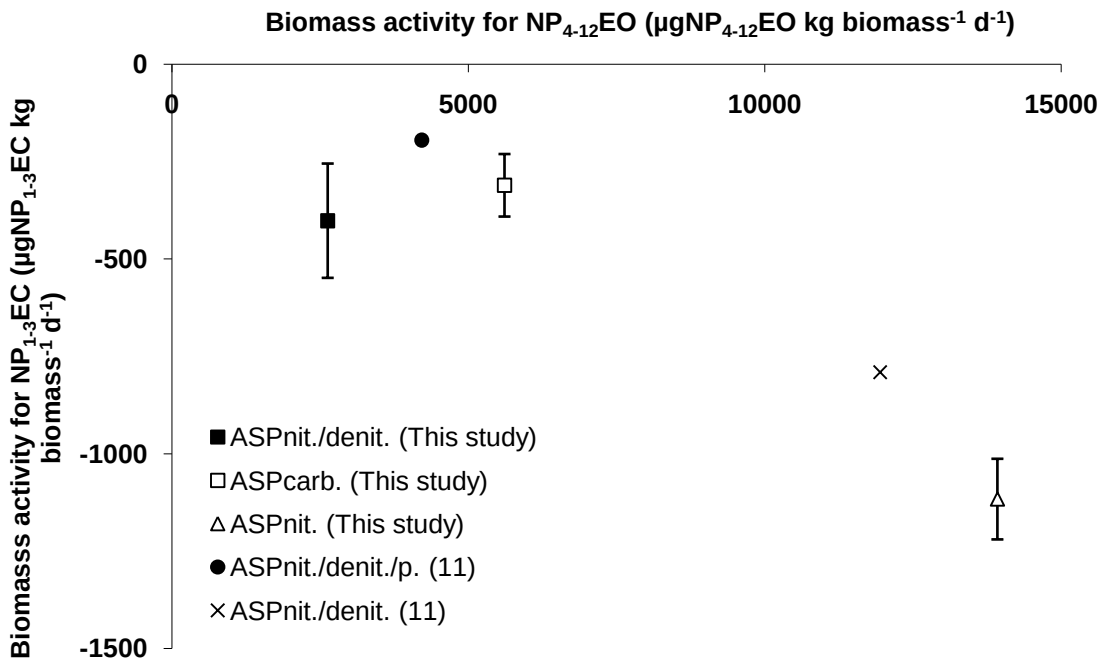


**Figure S2.** *Correlation between long chain nonylphenol polyethoxylate biomass activity ($\mu gNP_{4\text{-}12}EO$ kg biomass$^{-1}$ d$^{-1}$) and the formation of nonylphenoxy carboxylic acids as demonstrated by negative biomass activity ($\mu gNP_{1\text{-}3}EC$ kg biomass$^{-1}$ d$^{-1}$). Biomass activity calculated by: (settled sewage – final effluent)/ MLSS concentration in the secondary tank. Averaged data reported (n = 16, standard deviation plotted as error bars). Average data plotted from two additional sites detailed in Koh et al. (11) (standard deviation data not available).*

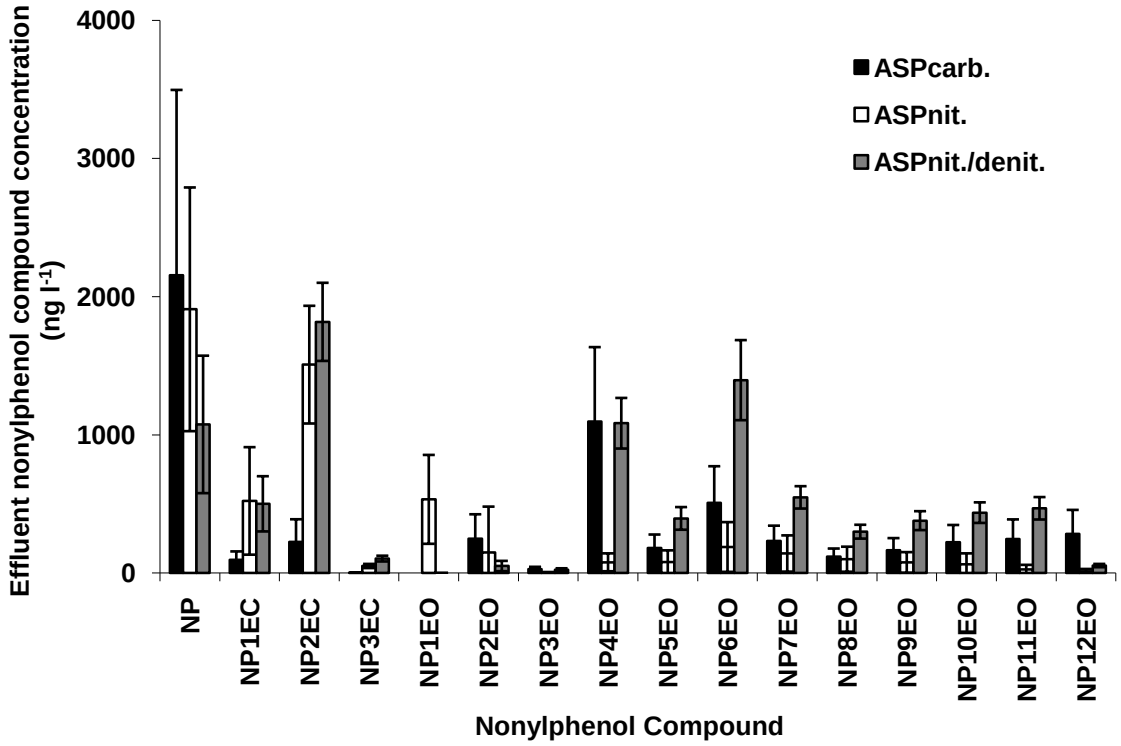


**Figure S3.** *Effluent nonylphenol compound concentrations from each site. (a) Carbonaceous activated sludge plant ($ASP_{carb.}$). (b) Nitrifying activated sludge plant ($ASP_{nit.}$). (c) Nitrifying/ denitrifying activated sludge plant ($ASP_{nit./denit.}$). Averaged data reported (n = 16), standard deviation plotted as error bars.*

**Table S1.** *Process characteristics/ typical operating conditions.*

| **Parameter** | | **$ASP_{carb.}$** | **$ASP_{nit.}$** | **$ASP_{nit./denit.}$** |
|---|---|---|---|---|
| **Biological process** | | ASP (carbonaceous/ non-nitrifying) | ASP (nitrifying) | Orbal (nitrifying/ denitrifying) |
| **Q** | ($m^3$ $d^{-1}$) | 15000 | 7.7 | 53085 |
| **Trade input** | (%) | 1-5 | <1[a] | <10 |
| **Volume** | ($m^3$) | 7379 | 1.8 | 53380 [b] |
| **HRT** | (h) | 8 | 5.6 | 16.9-26.4 |
| **SRT** | (d) | 6 | 20 | 22 |
| **MLSS** | (kg $m^{-3}$) | 4.3 | 4.5 | 2.4 |
| **F:M** | ($d^{-1}$) | 0.17 | 0.06 | 0.05 |
| **DO** | (g $m^{-3}$) | 6.0 | 6.5 | 8.0 |
| **pH** | In | 7.5 | 7 | 7.5 |
| | Out | 7.7 | 7 | 7.8 |
| **Temp.** | (°C) | 10 | 17 | 5.5 |
| | (°C) | 11.1 | 17 | 10.4 |
| | (°C) | 11.5 | 15 | 11.4 |

[a]exclusively hospital waste. [b]not including anoxic selecting tank (1728 $m^3$). Q, flow; HRT, hydraulic retention time; SRT, solids retention time; MLSS, Mixed liquor suspended solids; F:M, food to microorganisms ratio (mgBOD gMLSS $d^{-1}$); DO, dissolved oxygen. The variation for DO was ±0.5 g $m^{-3}$ for $ASP_{carb.}$ and $ASP_{nit.}$ and was ±1 g $m^{-3}$ for $ASP_{nit./denit.}$.

**Table S2.** *Average removal data of the three activated sludge plants*[a]

| Parameter | $ASP_{carb.}$ | | | $ASP_{nit.}$ | | | $ASP_{nit./denit.}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | In ($mg\ l^{-1}$) | Out ($mg\ l^{-1}$) | Removal (%) | In ($mg\ l^{-1}$) | Out ($mg\ l^{-1}$) | Removal (%) | In ($mg\ l^{-1}$) | Out ($mg\ l^{-1}$) | Removal (%) |
| **TSS** | 80.6 | 6.7 | 91.7 | 99 | 23 | 77 | 115.8 | 10.3 | 91.1 |
| **BOD** | 122.8 | 8.0 | 93.5 | 87 | 6 | 87 | 177 | 2.7 | 98.5 |
| **COD** | 299.6 | 47.6 | 84.1 | 141 | 24 | 83 | 422 | 36.3 | 91.4 |
| **$NH_4^+$-N** | 21.7 | 20.2 | 6.9 | 21.5 | <0.4 | 98 | 19.9 | 1.73 | 91.3 |
| **$NO_3^-$-N** | 3.3 | 2.8 | 15.1 | 0.39 | 30.9 | -7742 | 0.4 | 6.9 | -1625 |
| **$NO_2^-$-N** | 0.05 | 0.1 | -100 | N/a | N/a | N/a | 0.07 | 0.12 | -71.4 |

[a]All influent values based on settled sewage; units g $m^{-3}$. N/a, not analysed; TSS, total suspended solids; BOD, biological oxygen demand; COD, chemical oxygen demand; $NH_4^+$-N, ammoniacal nitrogen; $NO_3^-$, nitrate nitrogen; $NO_2^-$, nitrite nitrogen. The activated sludge plant TSS, COD, BOD, $NH_4^+$-N, $NO_3^-$-N and $NO_2^-$-N values are from daily duplicate samples average over the 5 day sampling period.

**Table S3.** *Apparent biomass sorption coefficient, log Kp (l kg$^{-1}$) for secondary activated sludge*

| | Activated Sludge Plants | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Koh et al. *(11)* | | This study | | | | | |
| | Return activated sludge (RAS) | | Return activated sludge (RAS) | | | Secondary effluent | | |
| | $ASP_{nit/denit}$ | $ASP_{nit/denit/P}$ | $ASP_{nit./denit.}$ | $ASP_{carb.}$ | $ASP_{nit.}$ | $ASP_{nit./denit.}$ | $ASP_{carb.}$ | $ASP_{nit.}$ |
| NP | 3.2 | 1.4 | 3.8 | 3.0 | 1.5 | 2.1 | 3.4 | 5.7 |
| NP1-2EO | 2.6 | 0.8 | 3.8 | 3.4 | 3.9 | 2.8 | 2.4 | 4.7 |
| NP3-12EO | 1.6 | 1.2 | 3.2 | 2.5 | 2.3 | 2.0 | 2.1 | 3.9 |
| NP1-12EO | 1.8 | 1.2 | 3.2 | 2.6 | 2.4 | 2.1 | 2.1 | 4.6 |
| NP1-3EC | 1.4 | 0.05 | 2.7 | 1.4 | 1.8 | 0.7 | 1.3 | 3.9 |