Supporting Information for

Impact of in-sewer degradation of pharmaceutical and personal care products (PPCPs) population markers on a population model

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S1. Comparison of sewer degradation of pharmaceutical and personal care product population markers observed in this study against other literature

Acesulfame

Acesulfame, an artificial sweetener, was considered stable under all sewer conditions as no significant difference from a slope of zero was observed over the study period. This is consistent with the Buerge et al. [1] finding that acesulfame is not eliminated during wastewater treatment and appears to be stable in the aquatic environment. Acesulfame can thus be used as stable marker to assess the degradation of other chemicals in the environment.

Atenolol

Atenolol, a beta blocker used primarily to treat angina and high blood pressure, was considered stable under all sewer conditions as no significant difference from a slope of zero was observed over the study period. While there are no other studies on aerobic degradation of atenolol, the available data for atenolol degradation under anaerobic pressurized sewer conditions indicate less than 20% removal during a 24 hour pass through the sewer pipe [2].

Caffeine

Under control conditions caffeine, a stimulant, remained stable over the 12 hour study period. However, under gravity sewer conditions, caffeine degraded rapidly fitting the first-order kinetics model with a half-life of 4 hours resulting in only 13% remaining after 12 hours. In the rising main degradation also fitted the first-order kinetics model with a half-life of 1.8 hours and only 1% remaining after the 12 hour study period. For control conditions, our data agree with others that caffeine is stable [3]. Other studies indicate that caffeine is readily degraded under microbial conditions such as when exposed to activated sludge leading to almost 100% removal during wastewater treatment [4].

Carbamazepine

Carbamazepine, an anticonvulsant, was considered stable under all sewer conditions as no significant difference from a slope of zero was observed over the study period. This is consistent with findings that carbamazepine is not removed during wastewater treatment [2, 5]. Additionally, in some cases effluent concentrations of carbamazepine were noticeably higher than the influent concentrations. Carbamazepine is highly soluble thus it is thought that desorption from solids alone cannot account for the increase and the increase may be a result of metabolites retransforming back to the parent compound [4, 6].

Codeine

In wastewater codeine, an opiate analgesic, remained stable with a slight increase (slope = 1.02) over the 12 hour study period. While in gravity and rising main reactors and in the presence of biofilm codeine degraded rapidly fitting the first-order kinetics models better and half-lives of 3.8 and 2.1 hours respectively which meant by 12 hours only 11% remained in the gravity sewer and less than 2% remained in the rising main.

This is contrary to Jelic et al. [2] who only observed a small amount of formation of codeine during the pass through their pressurised sewer. This is also contrary to other studies which found that removal of codeine during biological treatment was only 13% after 10 hours [6] however this may not be representative of sewer systems.

Furosemide

Furosemide, a strong diuretic, degraded under all sewer conditions and first-order kinetic models were the best fit for all conditions. Half-lives were consistent between the control and the gravity sewer with 5.7 and 5.8 hours. Under rising main conditions the half-life reduced to 1.9 hours. As a result less than 24% remained in the control and gravity sewers over the 12

hour study period and approximately only 1% remained in the rising main sewer. Jelic et al.[2] didn't see any removal of furosemide during a pass through a pressurised sewer and their data indicate that a small amount of furosemide formation may have occurred. Our results however indicate that furosemide undergoes both aerobic and anaerobic degradation. Data for removal during wastewater treatment is in the range of 40 and 80% [7].

Gabapentin

Gabapentin, an anticonvulsant, was considered stable under all sewer conditions as no significant difference from a slope of zero was observed over the study period. During wastewater treatment removal, trickling filters resulted in minimal removal of gabapentin but activated sludge resulted in 84% removal in one study [7] however only 6.4% in another [8].

Hydrochlorothiazide

Hydrochlorothiazide, a diuretic, was stable in the control with a small increase (linear regression slope = 1.39) and no significant deviation from zero in the gravity sewer. In the gravity sewer no significant difference from zero was observed over the 12 hour study period. In the rising main there was only limited degradation and neither linear regression nor first-order kinetic models fitted the data well. Elimination during wastewater treatment shows little to no removal of hydrochlorothiazide in some studies [9, 10] but up to 85% in others with no explanation for such large differences in results [11].

Ibuprofen

Ibuprofen, a non-steroidal anti-inflammatory, was considered stable under all sewer conditions as no significant difference from a slope of zero was observed over the study period. This is consistent with the finding of Jelic et al. [2] who found approximately only 5% removal during a single pass through a 7.6 km long pressurised sewer. During wastewater

treatment it has been observed that ibuprofen is effectively eliminated through bio-degradation processes in the range of 85 - 95% [7].

Iopromide

Iopromide, an imaging contrast agent, degraded under all conditions over the study period with first-order kinetics the best fitting model for all scenarios. In the control the half-life was about 16.8 hours where as in the gravity sewer and rising main it was 10.0 and 10.7 hours respectively. Elimination of iopromide in a conventional treatment plant has been observed at greater than 80% [12].

Naproxen

Naproxen, an analgesic, was found to only be stable in the control reactor with no significant deviation from zero during the study period. Both the gravity sewer and rising main showed linear decay with slopes of -3.15 and -3.26 respectively. This finding is inconsistent with that of Jelic et al. [2] who on average saw no removal through a single pass through their 7.6km long sewer pipe, however, their data indicate removal at between -20 and 10%. Removal during wastewater treatment has been observed at more than 90% [5].

Norfloxacin

Norfloxacin, a chemotherapeutic antibacterial agent, remained stable under control conditions with no significant deviation from zero during the 12 hour study period. In the gravity and rising main sewers, norfloxacin rapidly degraded with first-order kinetics indicating half-lives of 0.6. However, a non-zero plateau was observed for norfloxacin at approximately 16% of the initial concentration in the gravity sewer and 13% in the rising main and thus the half-lives given this plateau were 0.3 and 0.4 hours respectively. Data for removal of norfloxacin during wastewater treatment indicate 87-100% removal [4, 13, 14] with sorption rather than

degradation thought responsible for the removal. This may be a potential reason for the plateau observed if the liquid fraction has reached equilibrium with the solids.

Paracetamol

Paracetamol, an analgesic also called acetaminophen, was found to be stable under control conditions with no significant deviation from zero during the 12 hour study period. However, under gravity sewer and rising main conditions first-order kinetic models fitted well with half-lives of 1.5 hours 0.8 hours respectively. This is consistent with removal during wastewater treatment indicating that even though influent concentrations of paracetamol are high, removal in most cases is 100% [15].

Salicylic acid

Salicylic acid, a metabolite of acetyl salicylic acid which is an anti-inflammatory, was unstable under all conditions. For the control linear regression degradation was the best fit with a slope of -8.26 but for the gravity sewer and rising main first-order kinetic models fitted better with halves of 2.6 and 1.3 hours respectively. Studies on salicylic acid removal during wastewater treatment indicates that it is completely eliminated [16, 17].

Source	Compound	Retention Time (RT)	Quantitation Ion/Transition					Confirmation Ion/Transition					LOD	LOR	Supplier
			MRM (Q1 > Q3)	DP	EP	CE	CXP	MRM (Q1 > Q3)	DP	EP	CE	CXP			
ESI -	Acesulfame	3.3	162>82	-45	-10	-22	-5	162>78	-45	-10	-45	-5	0.02	0.10	Dr Ehrenstorfer
ESI -	Acesulfame-d_4	3.3	166>86	-45	-10	-22	-5	166>78	-45	-10	-45	-7	0.02	0.10	Toronto Research Chemicals
ESI +	Atenolol	2.47	267.2>190	60	10	27	9	267.2>145	60	10	38	9	0.02	0.05	Cerilliant
ESI +	Atenolol-d_7	2.47	274.1>145.1	70	10	37	10	274.1>190.1	70	10	28	8	0.02	0.05	Toronto Research Chemicals
ESI +	Caffeine	3.09	195.1>138.1	71	10	28	8	195.1>110.1	71	10	32	8	0.02	0.05	Cerilliant
ESI +	Caffeine-d_3	3.08	198.1>138	60	10	27	8	198.1>110	60	10	35	8	0.02	0.05	CDN Isotopes
ESI +	Carbamazepine	6.35	237.2>194	96	10	31	16	237.2>193	96	10	47	12	0.02	0.05	Cerilliant
ESI +	Carbamazepine-d_{10}	6.3	247.2>204.1	65	10	30	8	247.2>202.1	65	10	51	8	0.02	0.05	CDN Isotopes
ESI +	Codeine	2.61	300.2>215.1	60	10	37	12	300.2>165.1	60	10	57	10	0.04	0.10	Cerilliant
ESI -	Furosemide	6.46	329>285	-57	-10	-21	-13	329>205	-57	-10	-33	-13	0.04	0.10	Cerilliant
ESI +	Gabapentin	2.65	172.1>154	45	10	21	8	172.1>137	45	10	25	8	0.02	0.05	Cerilliant
ESI -	Hydrochlorothiazide	3.26	296>269	-85	-10	-28	-20	296>205	-85	-10	-34	-12	0.04	0.10	Cerilliant
ESI -	Hydrochlorothiazide-$C_{13}d_2$	3.>24	299>270.1	-85	-10	-28	-12	299>206.1	-85	-10	-35	-12	0.04	0.10	Toronto Research Chemicals
ESI -	Ibuprofen	9.56	205.1>161	-52	-10	-12	-10	205.1>159	-52	-10	-11	-10	0.20	0.50	Sigma-Aldrich Australia
ESI -	Iopromide	2.66	790.1>127	-80	-10	-55	-7	790>127	-80	-10	-55	-7	0.04	0.10	Dr Ehrenstorfer
ESI -	Naproxen	8	229.2>185.1	-53	-10	-11	-10	229.2>170.1	-53	-10	-22	-10	0.04	0.10	Cerilliant
ESI +	Norfloxacin	2.78	320.3>276.2	70	10	26	14	320.3>233.2	70	10	35	14	0.04	0.10	Sigma-Aldrich Australia
ESI +	Norfloxacin-d_5	2.78	325.2>281.2	70	10	28	15	325.2>238.2	70	10	36	15	0.04	0.10	Sigma-Aldrich Australia
ESI +	Paracetamol	2.83	152.1>110	56	10	>24	8	152.1>65.1	56	10	42	6	0.02	0.05	Cerilliant
ESI -	Salicylic Acid	5.6	137>93	-45	-10	->24	-6	137>65	-45	-10	-40	-6	0.04	0.10	Cerilliant

Notes: MRM = Multiple Reaction Monitoring, DP = Declustering Potential, EP = Entrance Potential, CE = Collision Cell Energy, CXP = Collision Cell Exit Potential ESI = Electrospray Ionisation, LOD = Level of Detection, LOR = Level of Reporting.

Table SI 1. LCMS/MS parameters using an Sciex API 6500Q mass spectrometer (AB/Sciex, Concord, Ontario, Canada) with an electrospray ionization (ESI) interface coupled to a Shimadzu Nexera HPLC system (Shimadzu Corp., Kyoto, Japan). Separation was achieved on a Luna C-18 (2) (3 µm 100 Å LC

Column 150 mm x 3 mm, Phenomenex) column using a mobile phase gradient of 1 to 95 % methanol with 0.1% acetic acid. LOD was calculated using 3 x the standard deviation of 8 replicate injections of low level spiked MilliQ, saline and bore water samples. LOR was calculated as 3 x the LOD.

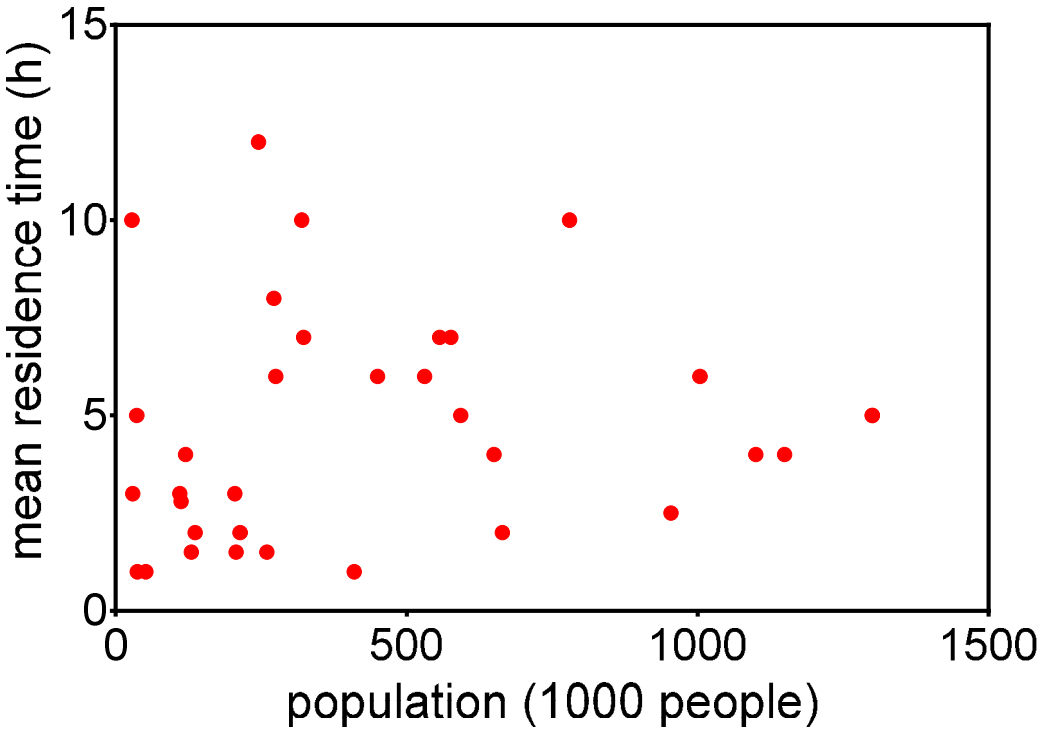
Chemical	pKa	Log K_{OW} Calculated	Experimental database match Log K_{ow}	Reference
acesulfame	5.67	-1.33		
atenolol	9.6	-0.03	0.16	[18]
caffeine	0.7 and 14	0.16	-0.07	[18]
carbamazepine	13.9	2.25	2.45	[19]
codeine	10.6	1.28	1.19	[20]
furosemide	3.8 and 7.5	2.32	2.03	[21]
gabapentin	3.68 and 10.70	-1.37	-1.1	[22]
hydrochlorothiazide	7.9 and 9.2	-0.1	-0.07	[18]
ibuprofen	4.91	3.79	3.97	[23]
iopromide	<2 and >13	-2.49	-2.05	[18]
naproxen	4.15	3.1	3.18	[18]
norfloxacin	6.32 and 8.47	-0.31	-1.03	[18]
paracetamol	9.38	0.27	0.46	[22]
salicylic acid	2.98	2.24	2.26	[18]

Log K_{OW} values reported for neutral molecule form and were calculated using the US EPA EPI Suite version 4.11 with KOWWIN version 1.68 [24].
pKa values were from SPARC (http://ibmlc2.chem.uga.edu/sparc); values given for -OH, -COOH, or highest NHx groups.

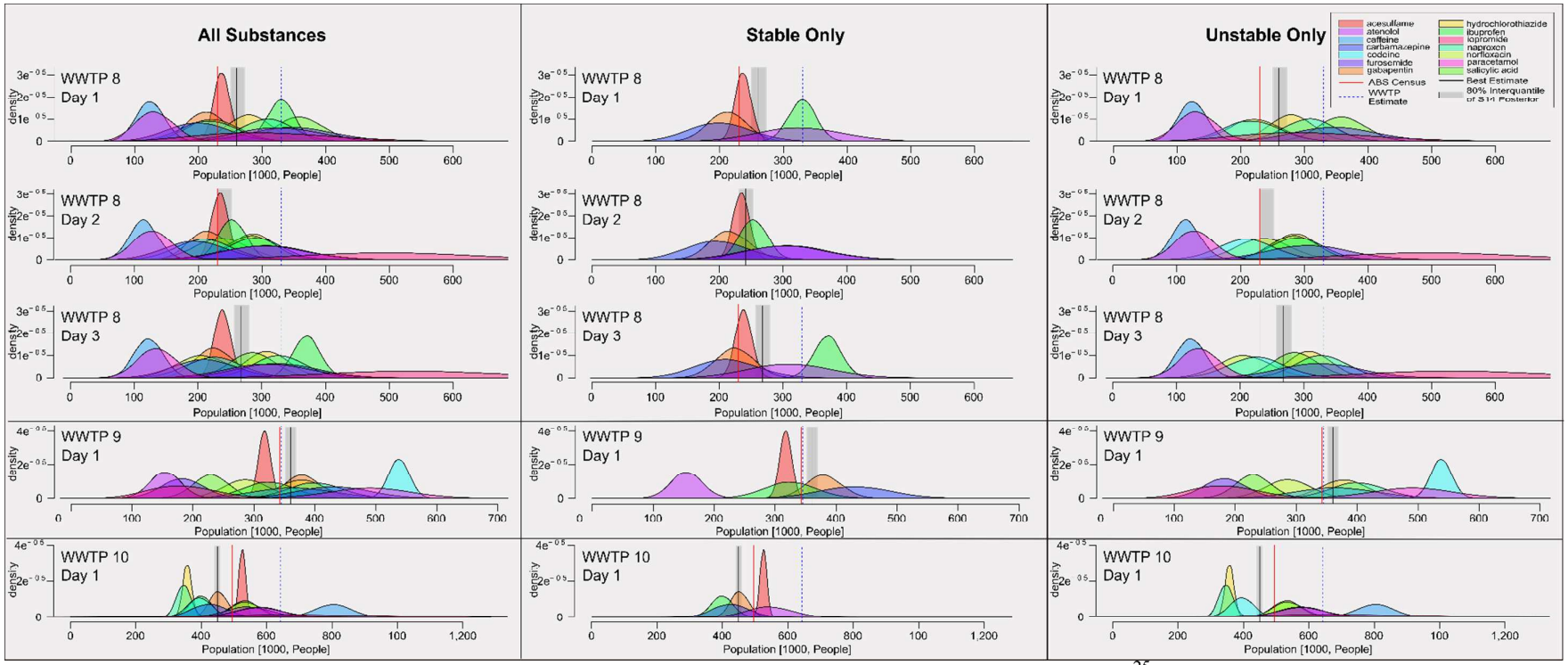
Table SI 2. Octanol/water partition coefficients both calculated using Episuite v4.11 and from experimental database matches.

Chemical	Correlation between mass load and population size R^2 (O'Brien et al. 2014)	Time before 10% loss (h)		
		Control	Gravity Sewer	Rising Main
acesulfame	0.995	>24.00	>24.00	>24.00
atenolol	0.823	>24.00	>24.00	>24.00
caffeine	0.869	>24.00	0.61	0.28
carbamazepine	0.849	>24.00	>24.00	>24.00
codeine	0.908	>24.00	0.57	0.32
furosemide	0.839	0.87	0.88	0.29
gabapentin	0.968	>24.00	>24.00	>24.00
hydrochlorothiazide	0.944	>24.00	>24.00	9.01
ibuprofen	0.919	>24.00	>24.00	>24.00
iopromide	0.377	2.55	1.52	1.63
naproxen	0.912	>24.00	3.17	3.07
norfloxacin	0.929	>24.00	0.09	0.09
paracetamol	0.811	>24.00	0.22	0.12
salicylic acid	0.922	1.21	0.40	0.20
Pearson r Correlation				
r		0.5127	0.3161	0.2721
95% confidence interval		-0.02456 to 0.8202	-0.2577 to 0.7251	-0.3021 to 0
R squared		0.2629	0.9994	0.07404
P value				
P (two-tailed)		0.0608	0.2708	0.3466
P value summary		ns	Ns	ns
Significant? (alpha = 0.05)		No	No	No
Number of XY Pairs		14	14	14

Table SI 3. Pearson correlation analysis between the R^2 for the correlation between mass load and population size from O'Brien et al. (2014) and the time before 10% loss in each of the sewer reactors .



SI Figure 1 Mean residence time versus population size from Ort et al. 2014



SI Figure 2 Individual substance distributions for estimating population size for all Large WWTPs from [25].

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