LEACHATE MASS

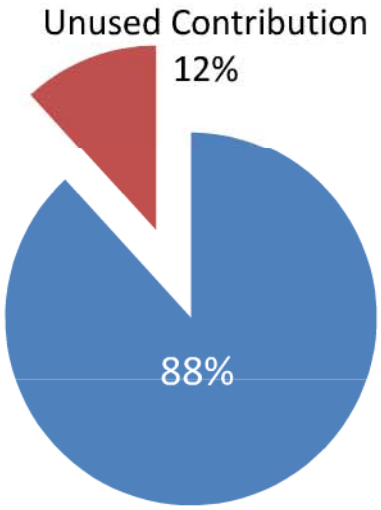
TOTAL APIs
human use only

Landfill Study Results

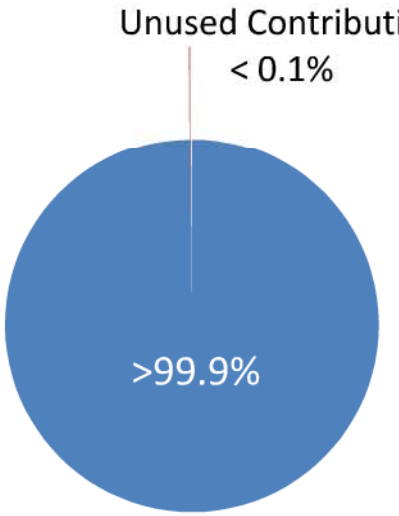
Relative contribution to surface water discharges

Patient Excretion Unused Medicine Disposal

EXCRETION MASS



All unused flushed



All unused to landfill

UNUSED AMOUNT

SURFACE WATER DISCHARGE

LEACHATE CONCENTRATIONS

COMPARISON TO MAINE

API's Included

Compound	API Qt (kg/year)
Acetaminophen	5,691,120
Albuterol Sulfate	3,569
Cimetidine	49,980
Ciprofloxacin	85,440
Codeine	15,095
Digoxin	229
Diltiazem	149,296
Doxycycline	32,784
Enalaprilat	772
Erythromycin-H2O	64,283
Fluoxetine	12,434
Gemfibrozil	231,530
Ibuprofen	1,035,229
Lincomycin	328
Metformin	1,597,887
Norfloxacin	2,700
Oxytetracycline	31
Paroxetine metabolite	19,474
Ranitidine	100,417
Sulfamethoxazole	314,389
Sulfathiazole	483
Tetracycline	68,569
Trimethoprim	64,450
Warfarin	3,999

Unused Medicine Amounts
5%, 10% and 15%

Compound	API Quantity (kg/year)	5% Unused (kg/year)	10% Unused (kg/year)	15% Unused (kg/year)
Acetaminophen	5,691,120	284,556	569,112	853,668
Albuterol Sulfate	3,569	178	357	535
Cimetidine	49,980	2,499	4,998	7,497
Ciprofloxacin	85,440	4,272	8,544	12,816
Codeine	15,095	755	1,510	2,264
Digoxin	229	11	23	34
Diltiazem	149,296	7,465	14,930	22,394
Doxycycline	32,784	1,639	3,278	4,918
Enalaprilat	772	39	77	116
Erythromycin-H2O	64,283	3,214	6,428	9,642
Fluoxetine	12,434	622	1,243	1,865
Gemfibrozil	231,530	11,577	23,153	34,730
Ibuprofen	1,035,229	51,761	103,523	155,284
Lincomycin	328	16	33	49
Metformin	1,597,887	79,894	159,789	239,683
Norfloxacin	2,700	135	270	405
Oxytetracycline	31	2	3	5
Paroxetine metabolite	19,474	974	1,947	2,921
Ranitidine	100,417	5,021	10,042	15,062
Sulfamethoxazole	314,389	15,719	31,439	47,158
Sulfathiazole	483	24	48	72
Tetracycline	68,569	3,428	6,857	10,285
Trimethoprim	64,450	3,223	6,445	9,668
Warfarin	3,999	200	400	600

Leachate Concentrations

Landfill Information

- Leachate generation = 169,989,602 L/yr
- Solids generation = 1.24×10^{11} kg/yr
  = 2.97×10^{11} L/yr

Partitioning

- Cunningham (Cunningham, V. L., 2004) has developed a methodology for calculating partition coefficient (Kp) values for APIs that adsorb to organic solids in wastewater treatment plants (WWTPs).
- This method uses the octanol-water partitioning coefficient of an API and its acidic or basic properties to calculate the compounds K_p value
- The API's K_p value is used to calculate its concentration in landfill leachate, based on the assumption that equilibrium occurs between the solid and aqueous phases in a landfill
- Organic solids in a MSW landfill will be adsorbent in a way that is similar to WWTP bio-solids

Leachate Concentrations cont.

				LEACHATE API CONCENTRATION IN ug/L								
				10% Sorption Efficiency			50% Sorption Efficiency			100% Sorption Efficiency		
Compound	**Log Kp**	**Anaerobic Biodegradation (fraction remaining)**	**Hydrolysis (fraction remaining)**	**5% Unused**	**10% Unused**	**15% Unused**	**5% Unused**	**10% Unused**	**15% Unused**	**5% Unused**	**10% Unused**	**15% Unused**
Acetaminophen	0.0025	0.0100	1.0000	94.7	**189.3**	284.0	19.0	38.0	57.1	9.5	19.0	28.5
Albuterol Sulfate	0.4000	1.0000	1.0000	2.4	**4.8**	7.2	0.5	1.0	1.4	0.2	0.5	0.7
Cimetidine	2.3192	1.0000	1.0000	0.4	**0.8**	1.2	0.1	0.2	0.2	0.0	0.1	0.1
Ciprofloxacin	-1.8457	1.0000	0.0100	251.3	**502.6**	753.9	251.3	502.6	753.9	251.3	502.6	753.9
Codeine	0.6863	1.0000	1.0000	5.2	**10.4**	15.7	1.0	2.1	3.1	0.5	1.0	1.6
Digoxin	0.0059	1.0000	0.0100	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diltiazem	3.0182	1.0000	1.0000	0.2	**0.5**	0.7	0.0	0.1	0.1	0.0	0.0	0.1
Doxycycline	0.0000	1.0000	1.0000	54.8	**109.7**	164.5	11.0	22.0	33.1	5.5	11.0	16.5
Enalaprilat	-1.0173	1.0000	1.0000	227.0	**454.0**	681.0	227.0	454.0	681.0	227.0	454.0	681.0
Erythromycin-H2O	3.2920	1.0000	1.0000	0.1	**0.1**	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Fluoxetine	3.2750	1.0000	1.0000	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gemfibrozil	0.5001	1.0000	1.0000	122.9	**245.9**	368.8	24.6	49.2	73.9	12.3	24.6	36.9
Ibuprofen	0.4356	1.0000	1.0000	637.6	**1,275.1**	1,912.7	127.7	255.4	383.2	63.9	127.8	191.6
Lincomycin	2.5111	1.0000	1.0000	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metformin	1.4489	1.0000	1.0000	95.6	**191.2**	286.8	19.1	38.2	57.4	9.6	19.1	28.7
Norfloxacin	-1.7729	1.0000	1.0000	794.2	**1,588.3**	2,382.5	794.2	1,588.3	2,382.5	794.2	1,588.3	2,382.5
Oxytetracycline	1.0127	1.0000	1.0000	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paroxetine metabolite	2.9946	1.0000	1.0000	0.0	**0.1**	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Ranitidine	1.5467	1.0000	1.0000	4.8	**9.6**	14.4	1.0	1.9	2.9	0.5	1.0	1.4
Sulfamethoxazole	2.7339	1.0000	1.0000	1.0	**2.0**	2.9	0.2	0.4	0.6	0.1	0.2	0.3
Sulfathiazole	1.9420	1.0000	1.0000	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetracycline	1.3420	1.0000	1.0000	5.2	**10.5**	15.7	1.0	2.1	3.1	0.5	1.0	1.6
Trimethoprim	2.5801	0.0010	1.0000	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Warfarin	1.0906	0.0100	1.0000	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Comparison to Maine Concentrations

Parameter Name	Hatch Hill Landfill, Augusta Primexpand III Conc. [ng/L]	Bath Municipal Landfill Leach-MH Conc. [ng/L]	Brunswick Municipal Landfill MH-P1 Conc. [ng/L]	Median of Three Landfills Conc. [ng/L]	PhRMA Predicted at 15% Unused Leachate Concentration Conc. [ng/L]	PhRMA Predicted at 10% Unused Leachate Concentration Conc. [ng/L]	PhRMA Predicted at 5% Unused Leachate Concentration Conc. [ng/L]
Acetaminophen	117,000	2,750		59,875	57,000	38,000	19,000
Albuterol	604	27	88	88	1,400	1,000	500
Cimetidine	25	149	60	60	200	200	100
Ciprofloxacin	269			269	753,900	502,600	251,300
Diltiazem	20		11	15	100	100	<100
Enalapril	41	3	3	3	681,000	454,000	227,000
Erythromycin-H2O	2,990	31	289	289	<100	<100	<100
Gemfibrozil	172	151	277	172	73,900	49,200	24,600
Ibuprofen	23,200	21,900	11,600	21,900	383,200	255,400	127,700
Lincomycin	64	73	278	73	<100	<100	<100
Metformin	14,800			14,800	57,400	38,200	19,100
Norfloxacin	449			449	2,382,500	1,588,300	794,200
Sulfathiazole	37		255	146	<100	<100	<100

Leachate Mass

Compound	Leachate Concentration in ug/l	Leachate API Mass (kg/yr)
Acetaminophen	189.3	32.2
Albuterol Sulfate	4.8	0.8
Cimetidine	0.8	0.1
Ciprofloxacin	502.6	85.4
Codeine	10.4	1.8
Digoxin	0.0	0.0
Diltiazem	0.5	0.1
Doxycycline	109.7	18.6
Enalaprilat	454.0	77.2
Erythromycin-H2O	0.1	0.0
Fluoxetine	0.0	0.0
Gemfibrozil	245.9	41.8
Ibuprofen	1,275.1	216.8
Lincomycin	0.0	0.0
Metformin	191.2	32.5
Norfloxacin	1,588.3	270.0
Oxytetracycline	0.0	0.0
Paroxetine metabolite	0.1	0.0
Ranitidine	9.6	1.6
Sulfamethoxazole	2.0	0.3
Sulfathiazole	0.0	0.0
Tetracycline	10.5	1.8
Trimethoprim	0.0	0.0
Warfarin	0.0	0.0

Based on: 10% Unused and 10% sorption Efficiency
Leachate Gener 169989601.7 L/yr

99.92% Retention in Landfill

Compound	API Quantity Disposed in Landfill (kg/yr)	Leachate API Mass (kg/yr)	% Retention in Landfill
Acetaminophen	569,112.0	32.2	99.99%
Albuterol Sulfate	356.9	0.8	99.77%
Cimetidine	4,998.0	0.1	100.00%
Ciprofloxacin	8,544.0	85.4	99.00%
Codeine	1,509.5	1.8	99.88%
Digoxin	22.9	0.0	99.99%
Diltiazem	14,929.6	0.1	100.00%
Doxycycline	3,278.4	18.6	99.43%
Enalaprilat	77.2	77.2	0.00%
Erythromycin-H2O	6,428.3	0.0	100.00%
Fluoxetine	1,243.4	0.0	100.00%
Gemfibrozil	23,153.0	41.8	99.82%
Ibuprofen	103,522.9	216.8	99.79%
Lincomycin	32.8	0.0	100.00%
Metformin	159,788.7	32.5	99.98%
Norfloxacin	270.0	270.0	0.00%
Oxytetracycline	3.1	0.0	99.94%
Paroxetine metabolite	1,947.4	0.0	100.00%
Ranitidine	10,041.7	1.6	99.98%
Sulfamethoxazole	31,438.9	0.3	100.00%
Sulfathiazole	48.3	0.0	99.99%
Tetracycline	6,856.9	1.8	99.97%
Trimethoprim	6,445.0	0.0	100.00%
Warfarin	399.9	0.0	100.00%
Aggregate	954,448.8	781.1	99.92%

Based on: 10% Unused and 10% sorption Efficiency

Excretion Mass

			API mass to POTW due to Patient Use (kg/yr)		
Compound	**API Qt (kg/year)**	**Loss by Human Metabolism (%)**	**5% Unused**	**10% Unused**	**15% Unused**
Acetaminophen	5,691,120	10	4,865,907.6	4,609,807.2	4,353,706.8
Albuterol Sulfate	3,569	72	949.4	899.4	849.4
Cimetidine	49,980	52	22,790.8	21,591.3	20,391.7
Ciprofloxacin	85,440	11	72,239.3	68,437.2	64,635.1
Codeine	15,095	10	12,906.4	12,227.2	11,547.9
Digoxin	229	16	182.7	173.1	163.5
Diltiazem	149,296	96	5,673.2	5,374.6	5,076.1
Doxycycline	32,784	0	31,144.9	29,505.7	27,866.5
Enalaprilat	772	10	659.9	625.1	590.4
Erythromycin-H2O	64,283	0	61,068.9	57,854.8	54,640.6
Fluoxetine	12,434	90	1,181.2	1,119.1	1,056.9
Gemfibrozil	231,530	24	167,164.7	158,366.5	149,568.4
Ibuprofen	1,035,229	78	216,362.9	204,975.3	193,587.8
Lincomycin	328	0	312.0	295.6	279.2
Metformin	1,597,887	0	1,517,992.6	1,438,098.2	1,358,203.9
Norfloxacin	2,700	7	2,385.5	2,259.9	2,134.4
Oxytetracycline	31	0	29.7	28.2	26.6
Paroxetine metabolite	19,474	0	18,500.3	17,526.6	16,552.9
Ranitidine	100,417	6	89,672.0	84,952.4	80,232.9
Sulfamethoxazole	314,389	88	35,840.3	33,954.0	32,067.7
Sulfathiazole	483	15	390.0	369.5	349.0
Tetracycline	68,569	0	65,141.0	61,712.5	58,284.0
Trimethoprim	64,450	15	52,043.4	49,304.3	46,565.1
Warfarin	3,999	92	303.9	287.9	271.9

0.013% of APIs in effluent discharges are from landfill leachate if all unused medicine is disposed of via landfill

Compound	API Mass to POTW from Patient Excretion (kg/yr)	Leachate API Mass (kg/yr)	POTW Removal (%)	API mass in POTW Effluent due to Patient Use (kg/yr)	API Mass in POTW Effluent from Unused Medicine in Landfills (kg/yr)	Percent of Total Effluent Load Resulting from Landfill Disposal
Acetaminophen	4,609,807.2	32.2	98	92,196.1	0.644	0.0007
Albuterol Sulfate	899.4	0.8	0	899.4	0.811	0.0901
Cimetidine	21,591.3	0.1	70	6,477.4	0.041	0.0006
Ciprofloxacin	68,437.2	85.4	74	17,793.7	22.214	0.1247
Codeine	12,227.2	1.8	46	6,602.7	0.959	0.0145
Digoxin	173.1	0.0	0	173.1	0.001	0.0007
Diltiazem	5,374.6	0.1	70	1,612.4	0.025	0.0015
Doxycycline	29,505.7	18.6	0	29,505.7	18.645	0.0632
Enalaprilat	625.1	77.2	30	437.6	54.024	10.9890
Erythromycin-H2O	57,854.8	0.0	66	19,670.6	0.006	0.0000
Fluoxetine	1,119.1	0.0	85	167.9	0.001	0.0003
Gemfibrozil	158,366.5	41.8	44	88,685.3	23.407	0.0264
Ibuprofen	204,975.3	216.8	90	20,497.5	21.675	0.1056
Lincomycin	295.6	0.0	0	295.6	0.001	0.0002
Metformin	1,438,098.2	32.5	7	1,337,431.4	30.229	0.0023
Norfloxacin	2,259.9	270.0	81	429.4	51.300	10.6724
Oxytetracycline	28.2	0.0	0	28.2	0.002	0.0062
Paroxetine metabolite	17,526.6	0.0	89	1,927.9	0.001	0.0001
Ranitidine	84,952.4	1.6	30	59,466.7	1.142	0.0019
Sulfamethoxazole	33,954.0	0.3	24	25,805.0	0.252	0.0010
Sulfathiazole	369.5	0.0	80	73.9	0.001	0.0009
Tetracycline	61,712.5	1.8	0	61,712.5	1.784	0.0029
Trimethoprim	49,304.3	0.0	29	35,006.0	0.000	0.0000
Warfarin	287.9	0.0	0	287.9	0.002	0.0006
Aggregate	6,859,745.6	781.1		1,807,184	227	0.0126

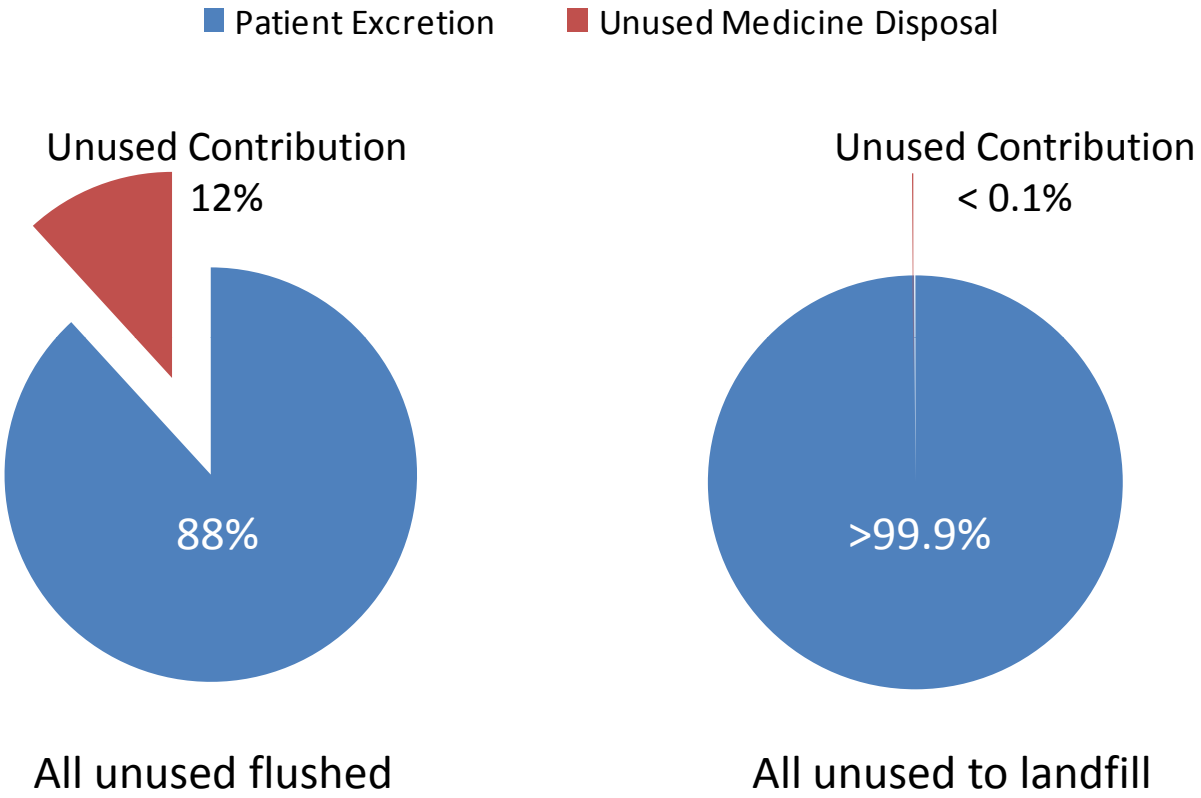
Based on: 10% Unused and 10% Landfill Sorption Efficiency

12% of APIs in effluent discharges are from unused medicine if all unused medicine is disposed of via sewer

Compound	API Mass to POTW from Patient Excretion (kg/yr)	Flushed API Mass (kg/yr)	POTW Removal (%)	API mass in POTW Effluent due to Patient Use (kg/yr)	API Mass in POTW Effluent from Unused Medicine Flushed (kg/yr)	Percent of Total Effluent Load from Flushing Unused Medicine
Acetaminophen	4,609,807.2	569,112.0	98	92,196.1	11,382.2	11.0
Albuterol Sulfate	899.4	356.9	0	899.4	356.9	28.4
Cimetidine	21,591.3	4,998.0	70	6,477.4	1,499.4	18.8
Ciprofloxacin	68,437.2	8,544.0	74	17,793.7	2,221.4	11.1
Codeine	12,227.2	1,509.5	46	6,602.7	815.1	11.0
Digoxin	173.1	22.9	0	173.1	22.9	11.7
Diltiazem	5,374.6	14,929.6	70	1,612.4	4,478.9	73.5
Doxycycline	29,505.7	3,278.4	0	29,505.7	3,278.4	10.0
Enalaprilat	625.1	77.2	30	437.6	54.0	11.0
Erythromycin-H2O	57,854.8	6,428.3	66	19,670.6	2,185.6	10.0
Fluoxetine	1,119.1	1,243.4	85	167.9	186.5	52.6
Gemfibrozil	158,366.5	23,153.0	44	88,685.3	12,965.7	12.8
Ibuprofen	204,975.3	103,522.9	90	20,497.5	10,352.3	33.6
Lincomycin	295.6	32.8	0	295.6	32.8	10.0
Metformin	1,438,098.2	159,788.7	7	1,337,431.4	148,603.5	10.0
Norfloxacin	2,259.9	270.0	81	429.4	51.3	10.7
Oxytetracycline	28.2	3.1	0	28.2	3.1	10.0
Paroxetine metabolite	17,526.6	1,947.4	89	1,927.9	214.2	10.0
Ranitidine	84,952.4	10,041.7	30	59,466.7	7,029.2	10.6
Sulfamethoxazole	33,954.0	31,438.9	24	25,805.0	23,893.6	48.1
Sulfathiazole	369.5	48.3	80	73.9	9.7	11.6
Tetracycline	61,712.5	6,856.9	0	61,712.5	6,856.9	10.0
Trimethoprim	49,304.3	6,445.0	29	35,006.0	4,576.0	11.6
Warfarin	287.9	399.9	0	287.9	399.9	58.1
Aggregate	6,859,745.6	954,448.8		1,807,184	241,470	12

Based on: 10% Unused disposed via sewer

Landfill Study Results



All unused flushed

All unused to landfill