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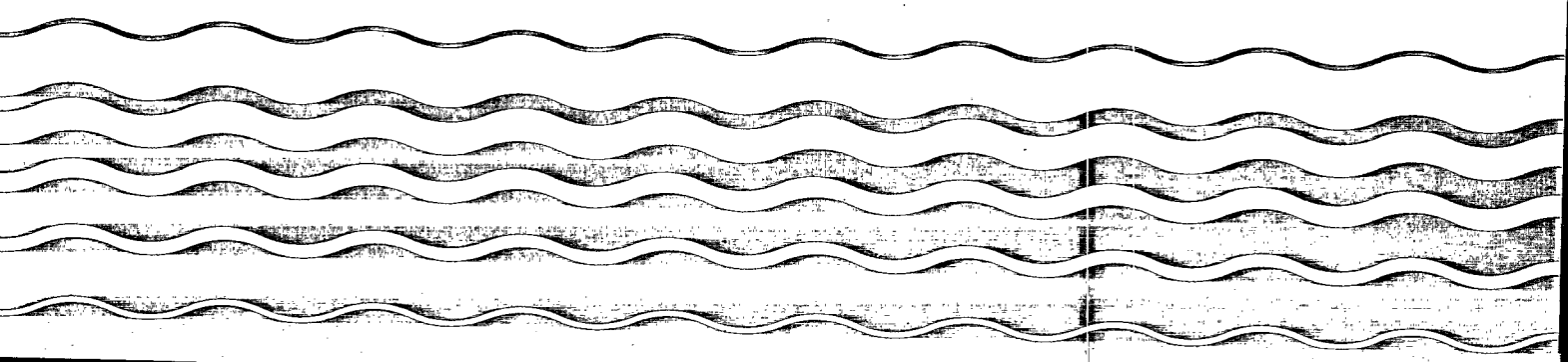

STATISTICAL SUPPORT DOCUMENT FOR THE PROPOSED EFFLUENT LIMITATIONS GUIDELINES FOR THE PHARMACEUTICAL MANUFACTURING INDUSTRY

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Statistical Support Document for the Proposed Effluent Limitations Guidelines for the Pharmaceutical Manufacturing Industry

1. Introduction

This document describes the statistical models and procedures used to estimate limitations supporting the proposed effluent guideline regulations for the pharmaceutical industry. These effluent limitations were estimated for technologies that formed the basis of the Best Practicable Control Technology Currently Available (BPT), Best Conventional Pollutant Control Technology (BCT), Best Available Technology Economically Achievable (BAT), New Source Performance Standards (NSPS), Pretreatment Standards for Existing Sources (PSES) and Pretreatment Standards for New Sources (PSNS).

2. Facility-level long-term means and variability factors

2.1 Ammonia and Priority and Nonconventional Organic Pollutants

Long-term means and variability factors were calculated from actual concentrations of constituents measured in pharmaceutical wastewaters treated by BAT treatment systems when such data were available. The data sets of daily effluent concentrations were obtained from pharmaceutical manufacturers' monitoring data as well as from EPA sampling episodes.

The long-term mean of each dataset was estimated by the arithmetic mean of the daily concentration values. Observations recorded as below the method detection limit were assigned a numerical value equal to the detection limit. The daily variability factor was calculated for all constituents (other than cyanide) by fitting a modified delta-lognormal distribution to daily concentration data. This distributional model has previously been used by EPA for other categories including the Organic Chemicals, Plastics and Synthetic Fibers (OCPSF), Pesticides Manufacturing, and Pulp and Paper industries.

The daily variability factor is defined as the estimated 99th percentile of the concentration distribution divided by the expected value of the concentration. The 4-day variability factor is defined similarly except that the 95th percentile of the distribution of 4-day averages is used instead of the 99th percentile of daily measurements. The description of the modified delta-lognormal model is presented below.

Modified delta-lognormal model

The modified delta-lognormal distribution models the effluent concentration data as a mixture of non-detects and measured values. This distribution is appropriate because the data for most constituents consisted of a mixture of measured values and non-detects. The modified delta-lognormal distribution assumes that each non-detected observation represents an actual concentration equal to the method detection limit, and the detected values are distributed according to a lognormal distribution.

The expected value, 99th percentile, and variability factor for the concentration of each constituent were estimated by fitting the data to a delta-lognormal distribution[1], modified to accommodate a non-zero value of the analytical method detection limit[2]. The following paragraphs describe this distribution and show how the variability factors and associated parameters were estimated from the data.

The modified delta-lognormal model is a mixture distribution in which the detected concentrations follow a standard lognormal distribution (ie, the logarithm of the concentration is assumed to be normally distributed with parameters mean μ and standard deviation σ). All nondetects are assumed to have a concentration value equal to the detection limit.

The cumulative distribution function, which gives the probability that an observed concentration (C) is less than or equal to some specified level (c), can be expressed as a function of the following quantities:

D = the detection limit,

δ = the probability of a nondetect,

I(c-D) = an indicator function which equals 1 for $c \geq D$ and 0 otherwise,

μ = the mean of the distribution of log transformed concentrations,

σ = the standard deviation of the distribution of log transformed concentrations,

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[1]Aitchison, J, and JAC Brown. 1957. *The Lognormal Distribution*. London: Cambridge University Press, pp. 95-96.

[2]This modification of the delta-lognormal distribution was used by EPA in establishing limitations guidelines for the Organic Chemicals, Plastics, and Synthetic Fibers point source category. The approach is therefore sometimes called the "Organics method."

y = variable of integration.

The equation of the cumulative distribution function is as follows:

$$F(C) = P(C \le C) = \delta I(C-D) + (1-\delta)\frac{1}{\sqrt{2\pi\sigma^2}}\int_0^C \frac{1}{y}\exp\left(-\frac{(\ln(y)-\mu)^2}{2\sigma^2}\right)dy. \quad (1)$$

The expected value E(C) of the actual concentration under this distribution function is given by

$$E(C) = \delta D + (1-\delta)\exp\left(\mu+\frac{\sigma^2}{2}\right), \quad (2)$$

and the variance V(C) is given by the following expression:

$$V(C) = (1-\delta)\exp(2\mu+\sigma^2)[\exp(\sigma^2)-(1-\delta)] + \delta(1-\delta)D[D-2\exp(\mu+\frac{\sigma^2}{2})]. \quad (3)$$

The 99th percentile of the distribution can be expressed in terms of μ, σ, and the inverse normal cumulative distribution function (Φ^{-1}), as follows:

$$C_{99} = \max\left(D, \exp\left(\mu+\sigma\Phi^{-1}\left(\frac{0.99-\delta}{1-\delta}\right)\right)\right). \quad (4)$$

Finally, the daily variability factor VF(1) is the 99th percentile divided by the expected value:

$$VF(1) = \frac{C_{99}}{E(C)} \quad (5)$$

The daily variability factors for each facility-constituent dataset were estimated by the following steps (for notational purposes let a typical dataset consist of n_1 detects, n_2 nondetects, and have concentration values X_i, $i=1,..,n_1$). The estimate, $\hat{\mu}$, of the log mean was calculated by taking the arithmetic average of the log transformed detects:

$$\hat{\mu} = \frac{1}{n_1}\sum_{i=1}^{n_1}\ln(X_i) \quad (6)$$

The estimate, $\hat{\sigma}$, of the log standard deviation was calculated by taking the square root of the sum of the squared differences between the log concentrations and $\hat{\mu}$, divided by the number of detects minus one:

$$\hat{\sigma} = \sqrt{\frac{1}{n_1 - 1} \sum_{i=1}^{n_1} (\ln(X_i) - \hat{\mu})^2} \qquad (7)$$

The estimated probability of a nondetect, $\hat{\delta}$, was calculated by dividing the number of nondetects by the number of observations:

$$\hat{\delta} = \frac{n_2}{n_1 + n_2} \qquad (8)$$

These quantities were then substituted into equations (2) and (4) to give estimates $\hat{E}(C)$ and $\hat{C}_{99}$ of the mean concentration and the 99th percentile, respectively. Finally, the resulting estimated mean and 99th percentile were substituted into equation (5) to yield the daily variability factor estimate, $\hat{V}F(1)$.

The average daily variability factor multiplied by the median long-term mean yields the value used by EPA as the maximum value that an individual concentration measurement can be expected to attain. An analogous measure of the maximum value attained by the means of four daily concentration measurements can also be defined and estimated from the data. The definition of the 4-day variability factor, VF(4), is the 95th percentile of the distribution of 4-day means, divided by the expected value of 4-day means.

The value of VF(4) can be estimated from the daily concentration data by exploiting the statistical properties of the 4-day mean, C_4, and approximating the distribution of C_4 by the modified delta-lognormal model. This approximation has been shown to provide a good estimate to the actual distribution[3]. To develop the estimate of VF(4), first note that the logarithm of C_4 is normally distributed with unknown mean and standard deviation denoted by μ_4 and σ_4, respectively. Also, $E(C_4) = E(C)$ because the expected value of a sum of random variables divided by a constant is equal to the sum of their expectations divided by that constant. And $V(C_4) = V(C)/4$ because the variance of a sum of independent random variables divided by a constant is equal to the sum of their variances divided

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[3]Barakat, R. 1976. Sums of Independent Lognormally Distributed Random Variables. *Journal of the Optical Society of America*. 66:211-16.

by the constant[4]. Finally, the probability that C_4 is a nondetect is δ^4, since the mean of four independent concentrations is a nondetect only if all four are nondetects, and the probability of this occurring is equal to the product of the component probabilities, or δ^4 if the daily nondetect probability is δ.

The following equations therefore hold:

$$E(C_4) = E(C) = \delta^4 D + (1-\delta^4)\ \exp\left(\mu_4 + \frac{\sigma_4^2}{2}\right), \tag{9}$$

$$V(C_4) = \frac{1}{4} V(C) = (1-\delta^4)\exp(2\mu_4+\sigma_4^2)\ (\exp(\sigma_4^2) - (1-\delta^4)) + \delta^4(1-\delta^4) D\left(D - 2\exp\left(\mu_4 + \frac{\sigma_4^2}{2}\right)\right), \tag{10}$$

and

$$C_{95}(4) = \max\left(D, \exp\left(\mu_4 + \sigma_4 \Phi^{-1}\left(\frac{0.95-\delta^4}{1-\delta^4}\right)\right)\right). \tag{11}$$

Equations (9) and (10) can be algebraically solved for σ_4 in terms of the mean and variance of the daily concentrations, the probability of a nondetect, and the detection limit. This expression is as follows:

$$\sigma_4 = \ln\left(1 + \frac{V(C)}{4\,(E(C) - \delta^4 D)^2} - \frac{\delta^4(1-\delta^4) D^2}{(E(C) - \delta^4 D)^2} + \frac{2\delta^4 D}{E(C) - \delta^4 D}\right) + \ln(1-\delta^4)\,. \tag{12}$$

To derive an estimate, $\hat{\sigma}_4$, of the left-hand side of equation (12), each quantity on the right-hand side was replaced by its estimate computed from the daily concentration data; i.e., E(C) was replaced by $\hat{E}(C)$, V(C) by $\hat{V}(C)$, and δ by $\hat{\delta}$. Next, the estimated $\hat{\sigma}_4$ together with $\hat{\delta}$ and $\hat{E}(C)$ were substituted into (9), which was solved to yield an estimate $\hat{\mu}_4$ of μ_4. Finally, μ_4 and σ_4 in (11) were replaced by their estimates to yield an estimated value of the 95th percentile of the 4-day mean distribution, and this estimate was divided by $\hat{E}(C)$ to give the estimated variability factor $\hat{V}F(4)$.

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[4]Cramer, H. 1963. *Mathematical Methods of Statistics*. Princeton University Press. pp. 173-180.

The results of applying the modified delta-lognormal model are shown in Tables 1, 2, and 3, which give the estimated long-term means and variability factors of constituent concentrations for facilities using advanced biological treatment, in-plant steam stripping, and in-plant steam stripping with distillation, respectively. Note that variability factors could not be estimated for facility datasets that had fewer than three detected concentrations as indicated by the dot in the VF column.

Table 1. Variability factors and long-term means for Advanced Biological Treatment

ANALYTE	FACILITY CODE	SOURCE	SAMPLE SITE	NO. OF OBS.	PERCENT OF NONDET.	UNITS	DET. LIMIT	MIN. DETECT	SAMPLE LONG-TERM MEAN	SAMPLE MAX.	DAILY VF	4-DAY VF
ACETONE	30540	I	FC	10	50.00	UG/L	50.00	55.0	136.90	800.00	8.17184	2.62475
ACETONE	30623	I	SE	19	42.11	UG/L	50.00	52.0	66.42	130.00	2.34136	1.34904
ACETONE	30701	P	FIL/EOP	242	96.69	UG/L	1000.00	1000.0	1078.51	8000.00	3.64777	1.56822
ACETONE	30949	3	SE	2	0.00	UG/L	10.00	29.0	89.50	150.00	.	.
ACETONITRILE	30623	I	SE	19	100.00	UG/L	5.00	.	5.00	5.00	.	.
AMMONIA	30540	I	FC	8	0.00	MG/L	1.40	1.4	2.56	3.70	1.89382	1.26333
BENZENE	30540	A	FC	1	100.00	UG/L	40.00	.	40.00	40.00	.	.
BENZENE	30540	S	FC	1	100.00	UG/L	10.00	.	10.00	10.00	.	.
BENZENE	30600	S	SPE	1	0.00	UG/L	120.00	120.0	120.00	120.00	.	.
BENZENE	30623	P	SE	3	100.00	UG/L	2.00	.	2.00	2.00	.	.
BENZENE	30623	S	SE	1	100.00	UG/L	10.00	.	10.00	10.00	.	.
BENZENE	30701	S	PPE	2	100.00	UG/L	0.01	.	0.01	0.01	.	.
CARBON TETRACHLORIDE	30050	S	SE	1	100.00	UG/L	0.01	.	0.01	0.01	.	.
CHLOROBENZENE	30623	S	SE	1	100.00	UG/L	10.00	.	10.00	10.00	.	.
CHLOROFORM	30050	S	SE	1	0.00	UG/L	8.10	8.1	8.10	8.10	.	.
CHLOROFORM	30050	V	SE	3	100.00	UG/L	1.00	.	1.00	1.00	.	.
CHLOROFORM	30540	I	FC	10	100.00	UG/L	10.00	.	10.00	10.00	.	.
CHLOROFORM	30540	S	FC	1	100.00	UG/L	10.00	.	10.00	10.00	.	.
CHLOROFORM	30600	S	SPE	1	0.00	UG/L	110.00	110.0	110.00	110.00	.	.
CHLOROFORM	30623	I	SE	19	57.89	UG/L	10.00	10.0	12.63	24.00	2.30398	1.33029
CHLOROFORM	30623	P	SE	3	0.00	UG/L	9.00	9.0	13.33	18.00	2.10986	1.31781
CHLOROFORM	30701	S	PPE	2	0.00	UG/L	0.90	0.9	1.85	2.80	.	.
CHLOROFORM	31108	3	SE	2	50.00	UG/L	1.70	220.0	110.85	220.00	.	.
CHLOROMETHANE	30540	I	FC	10	90.00	UG/L	50.00	124.0	53.40	124.00	.	.
CHLOROMETHANE	30623	I	SE	19	100.00	UG/L	50.00	.	50.00	50.00	.	.
ETHANOL	30540	I	FC	10	90.00	UG/L	500.00	5515.0	1001.50	5515.00	.	.

Table 1. Variability factors and long-term means for Advanced Biological Treatment

ANALYTE	FACILITY CODE	SOURCE	SAMPLE SITE	NO. OF OBS.	PERCENT OF NONDET.	UNITS	DET. LIMIT	MIN. DETECT	SAMPLE LONG-TERM MEAN	SAMPLE MAX.	DAILY VF	4-DAY VF
ETHANOL	30623	I	SE	20	85.00	UG/L	500	500	530.00	800	1.9342	1.21086
ETHANOL	30701	P	FIL/EOP	242	93.39	UG/L	1000	1000	1074.38	10000	3.0073	1.46986
ETHYL ACETATE	30540	I	FC	10	90.00	UG/L	500	600	510.00	600	.	.
ETHYL ACETATE	30701	P	FIL/EOP	242	100.00	UG/L	1000	.	1000.00	1000	.	.
FORMALDEHYDE	30623	I	SE	9	0.00	UG/L	120	120	343.33	800	4.3100	1.81518
HEPTANE	30623	I	SE	19	100.00	UG/L	5	.	5.00	5	.	.
HEXANE	30623	I	SE	19	100.00	UG/L	5	.	5.00	5	.	.
ISOPROPANOL	30540	I	FC	10	100.00	UG/L	500	.	500.00	500	.	.
ISOPROPANOL	30949	3	SE	2	100.00	UG/L	100	.	62.50	100	.	.
ISOPROPYL ACETATE	30540	I	FC	10	100.00	UG/L	500	.	500.00	500	.	.
METHANOL	30540	I	FC	10	0.00	UG/L	2260	2260	13560.00	87560	6.6575	2.33730
METHANOL	30623	I	SE	20	90.00	UG/L	500	300	650.00	3700	.	.
METHANOL	30701	P	FIL/EOP	242	100.00	UG/L	1000	.	1000.00	1000	.	.
METHYLENE CHLORIDE	30349	S	SE	1	0.00	UG/L	250	250	250.00	250	.	.
METHYLENE CHLORIDE	30540	S	FC	1	0.00	UG/L	140	140	140.00	140	.	.
METHYLENE CHLORIDE	30600	S	SPE	1	0.00	UG/L	2600	2600	2600.00	2600	.	.
METHYLENE CHLORIDE	30623	I	SE	19	78.95	UG/L	10	26	109.58	1095	18.3879	4.20528
METHYLENE CHLORIDE	30623	P	SE	3	0.00	UG/L	4	4	68.67	110	13.4512	3.81305
METHYLENE CHLORIDE	30623	S	SE	1	100.00	UG/L	10	.	10.00	10	.	.
METHYLENE CHLORIDE	30704	3	SE	1	100.00	UG/L	40	.	40.00	40	.	.
METHYLENE CHLORIDE	30949	3	SE	2	0.00	UG/L	5	17	19.50	22	.	.
N-BUTANOL	30949	3	SE	2	100.00	UG/L	250	.	250.00	250	.	.
N,N-DIMETHYLFORMAMID	30623	I	SE	20	95.00	UG/L	10	35	11.25	35	.	.
PHENOL	30050	V	SE	2	0.00	UG/L	3	3	3.00	3	.	.
PHENOL	30623	I	SE	20	85.00	UG/L	10	16	11.65	25	2.4959	1.37214
PHENOL	30623	S	SE	1	100.00	UG/L	10	.	10.00	10	.	.

Table 1. Variability factors and long-term means for Advanced Biological Treatment

ANALYTE	FACILITY CODE	SOURCE	SAMPLE SITE	NO. OF OBS.	PERCENT OF NONDET.	UNITS	DET. LIMIT	MIN. DETECT	SAMPLE LONG-TERM MEAN	SAMPLE MAX.	DAILY VF	4-DAY VF
PYRIDINE	30949	3	SE	2	100.00	UG/L	10.00	.	10.00	10.00	.	.
TETRAHYDROFURAN	30623	I	SE	20	15.00	UG/L	5.00	20	1222.95	3484.00	12.2719	3.55499
TOLUENE	30050	S	SE	1	100.00	UG/L	0.01	.	0.01	0.01	.	.
TOLUENE	30050	V	SE	3	100.00	UG/L	1.00	.	1.00	1.00	.	.
TOLUENE	30540	I	FC	10	100.00	UG/L	10.00	.	10.00	10.00	.	.
TOLUENE	30600	S	SPE	1	0.00	UG/L	180.00	180	180.00	180.00	.	.
TOLUENE	30623	I	SE	19	100.00	UG/L	10.00	.	10.00	10.00	.	.
TOLUENE	30623	P	SE	3	66.67	UG/L	2.00	53	19.00	53.00	.	.
TOLUENE	30623	S	SE	1	100.00	UG/L	10.00	.	10.00	10.00	.	.
TOLUENE	30701	P	FIL/EOP	242	100.00	UG/L	1000.00	.	1000.00	1000.00	.	.
TOLUENE	30701	S	PPE	2	100.00	UG/L	0.01	.	0.01	0.01	.	.
TRICHLOROFLUOROMETHA	30540	I	FC	10	10.00	UG/L	10.00	10	18.25	43.00	2.7344	1.46762
TRICHLOROFLUOROMETHA	30600	S	SPE	1	0.00	UG/L	420.00	420	420.00	420.00	.	.
TRIETHYLAMINE	30949	3	SE	2	100.00	UG/L	50.00	.	50.00	50.00	.	.
XYLENES	30540	I	FC	10	100.00	UG/L	10.00	.	10.00	10.00	.	.
XYLENES	30540	I	FC	10	100.00	UG/L	10.00	.	10.00	10.00	.	.
1,2-DICHLOROETHANE	30623	I	SE	19	15.79	UG/L	10.00	11	64.16	263.00	6.8272	2.36887
1,2-DICHLOROETHANE	30623	P	SE	3	33.33	UG/L	2.00	3	38.33	110.00	.	.
1,2-DICHLOROETHANE	30623	S	SE	1	0.00	UG/L	500.00	500	500.00	500.00	.	.
1,4-DICHLOROBENZENE	31108	3	SE	2	100.00	UG/L	1.00	.	1.00	1.00	.	.
1,4-DIOXANE	30540	I	FC	10	90.00	UG/L	10.00	463	55.30	463.00	.	.
2-BUTANONE	30623	I	SE	19	94.74	UG/L	50.00	65	50.79	65.00	.	.
2-METHYLPYRIDINE	30540	I	FC	10	100.00	UG/L	50.00	.	50.00	50.00	.	.
4-METHYL-2-PENTANONE	30540	I	FC	10	100.00	UG/L	50.00	.	50.00	50.00	.	.
4-METHYL-2-PENTANONE	30949	3	SE	2	100.00	UG/L	10.00	.	10.00	10.00	.	.

Table 2. Variability factors and long-term means for In-plant Steam Stripping

ANALYTE	FACILITY CODE	SAMPLE SITE	NO. OF OBS.	PERCENT OF NONDET.	UNITS	DET. LIMIT	MIN. DETECT	SAMPLE LONG-TERM MEAN	SAMPLE MAX.	DAILY VF	4-DAY VF
CHLOROFORM	30329	PC	16	100.00	UG/L	10	.	10.00	.	.	.
		PC/PILOT-T	8	100.00	UG/L	10	.	10.00	.	.	.
ETHANOL	30329	PC/B45	11	0.00	UG/L	.	102223	693371.27	1331570	4.3821	1.83092
		PC/PILOT-C	16	50.00	UG/L	500	3000	8231.25	36000	8.1578	2.63772
ISOPROPANOL	30329	PC/B45	11	45.45	UG/L	99000	22357	146486.09	369714	8.2380	2.69990
		PC/PILOT-C	16	50.00	UG/L	500	2100	6125.00	21900	7.4029	2.50152
METHANOL	30329	PC/BENCH	5	0.00	UG/L	.	120000	1374000.00	3900000	8.4810	2.76344
		PC/PILOT-C	16	0.00	UG/L	.	46000	473925.00	1300000	9.8162	3.08106
		PC/PILOT-T	8	0.00	UG/L	.	60000000	85000000.00	120000000	1.7183	1.21729
METHYLENE CHLORIDE	30329	PC	16	81.25	UG/L	10	192	58.06	398	8.0863	2.78545
METHYLENE CHLORIDE	30487	PC	23	95.65	UG/L	100	101	100.04	101	.	.
METHYLENE CHLORIDE	30618	PC	19	100.00	UG/L	1000	.	3842.11	.	.	.
PYRIDINE	30487	PC	1	100.00	UG/L	1000	.	1000.00	.	.	.
TETRAHYDROFURAN	30329	PC	5	0.00	UG/L	.	220	1542.00	2570	5.9701	2.18155
TOLUENE	30329	PC/BENCH	5	0.00	UG/L	.	333	473.20	630	1.6922	1.21028
		PC/B45	6	50.00	UG/L	1000	124	1125.83	2414	10.2576	3.36084
		PC/PILOT-C	16	50.00	UG/L	10	27	21.94	42	1.9807	1.48040
		PC/PILOT-T	8	87.50	UG/L	10	12	10.25	12	.	.
TOLUENE	30487	PC	23	100.00	UG/L	100	.	100.00	.	.	.
2-BUTANONE (MEK)	30329	PC	11	0.00	UG/L	.	4697	121237.91	392212	11.8742	3.54418
2-PROPANONE (ACETONE)	30329	PC	16	0.00	UG/L	.	197	3000.38	9677	10.4546	3.23076

Table 3. Variability factors and long-term means for In-plant Steam Stripping with Distillation

ANALYTE	FACILITY CODE	SAMPLE SITE	NO. OF OBS.	PERCENT OF NONDET.	UNITS	DET. LIMIT	MIN. DETECT	SAMPLE LONG-TERM MEAN	SAMPLE MAX.	DAILY VF	4-DAY VF
CHLOROFORM	30329	PC	16	100.00	UG/L	10	.	10.00	.	.	.
		PC/PILOT-T	8	100.00	UG/L	10	.	10.00	.	.	.
METHANOL	30767	UNKNOWN	65	30.77	UG/L	500	500	1518.46	11100	5.47835	2.06475
METHYLENE CHLORIDE	30329	PC	16	81.25	UG/L	10	192	58.06	398	8.08626	2.78545
METHYLENE CHLORIDE	30487	PC	23	95.65	UG/L	100	101	100.04	101	.	.
METHYLENE CHLORIDE	30618	PC	19	100.00	UG/L	1000	.	3842.11	.	.	.
PYRIDINE	30487	PC	1	100.00	UG/L	1000	.	1000.00	.	.	.
TETRAHYDROFURAN	30329	PC	5	0.00	UG/L	.	220	1542.00	2570	5.97012	2.18155
TOLUENE	30329	PC/BENCH	5	0.00	UG/L	.	333	473.20	630	1.69220	1.21028
		PC/B45	2	50.00	UG/L	1000	124	562.00	124	.	.
		PC/PILOT-C	16	50.00	UG/L	10	27	21.94	42	1.98075	1.48040
		PC/PILOT-T	8	87.50	UG/L	10	12	10.25	12	.	.
TOLUENE	30487	PC	23	100.00	UG/L	100	.	100.00	.	.	.
2-BUTANONE (MEK)	30329	PC	7	0.00	UG/L	.	4697	25812.71	99406	6.24302	2.24305
2-PROPANONE (ACETONE)	30329	PC	8	0.00	UG/L	.	197	388.88	769	3.06842	1.54190

2.2 BOD, COD, and TSS

The calculation of variability factors and long-term means was based on actual concentrations of BOD, COD, and TSS measured in pharmaceutical wastewaters treated by advanced biological treatment systems. A 1-day and 30-day average variability factor and limitation was estimated for each dataset from a modified delta-lognormal distribution that was fit to the data. The facility limitations were averaged to derive the overall 1-day and 30-day maximum limitations.

The 1-day facility-level variability factors were computed as described above in Section 2.1. An alternative approach was taken to estimate the 30-day average variability factor in order to account for additional variability due to the day-to-day correlation in concentrations of BOD, COD, and TSS. The adjustment factor was based on fitting a lag-1 autocorrelation time series model from adjacent day observations. This time-series model has been used by EPA in the OCPSF, pesticides, and pulp and paper rulemakings.

A lag-1 autocorrelation was computed directly from each facility dataset when possible; an average over all such computed lag-1 autocorrelations was transferred to datasets with insufficient numbers of adjacent day observations for direct estimation. The autocorrelation adjustment factor is described below.

Adjustment of 30-day variability factor for autocorrelation

The methodology to calculate 30-day variability factors for BOD, COD and TSS assumes that (1) the time series of daily concentration measurements for each pollutant is stationary (ie, there is no time trend present), and (2) the lag-k autocorrelations follow a first order autoregressive model (ie, the correlation of measurements taken k days apart is equal to the lag-1 correlation raised to the k^{th} power). These assumptions and the central limit theorem approximation that 30-day means are normally distributed lead to the following formula for the 30-day variability factor:

$$VF(30) = 1 + 1.645 \left(\frac{(e^{\hat{\sigma}^2} - 1) f_{30}(\hat{\rho})}{30} \right)^{0.5} \qquad (13)$$

where the lag-1 autocorrelation, ρ, and the standard deviation, σ, are estimated from the time series data, and the factor f_{30} is given by the following expression

$$f_{30}(\rho) = 1 + \frac{2}{30} \sum_{k=1}^{29} \frac{(30-k)\,[\exp(\rho^k \sigma^2) - 1]}{\exp(\sigma^2) - 1} \qquad (14)$$

When assumption (2) does not hold, the formula for computing the f_{30} factor is obtained by replacing ρ^k in equation (2) with the general lag-k autocorrelation, ρ_k.

The results of applying the modified delta-lognormal model and autocorrelation adjustment are shown in Table 3, which gives the estimated means, 1- and 30-day variability factors, and limitations for BOD, COD, and TSS.

Table 4. BOD, COD, and TSS 1- and 30-day variabliity factors Adjusted for autocorrelation

ANALYTE	FACILITY CODE	SAMPLE SITE	NO. OF OBS.	UNIT	LAG-1 AUTO CORRELATION	MIN. DETECT	SAMPLE MEAN	SAMPLE MAX.	DAILY LIMITATION	30 DAY LIMITATION	DAILY VF	30 DAY VF
BOD5	12053	E	39	MG/L	0.59595	2.000	5.87	13.00	16.33	7.63	2.76670	1.29233
BOD5	12053	E	39	PPD	0.01154	0.232	0.91	2.39	2.96	1.09	3.22390	1.18938
BOD5	12317	E	51	MG/L	0.59595	1.000	4.53	18.00	19.91	6.70	4.39433	1.47886
BOD5	50001	600	362	MG/L	0.50232	1.100	9.04	62.00	32.86	12.21	3.63105	1.34899
BOD5	50001	200	363	MG/L	0.20280	60.000	1031.29	12000.00	4415.70	1349.55	4.26077	1.30220
BOD5	50002	410	354	MG/L	0.78486	3.000	40.30	174.00	143.41	62.32	3.52482	1.53186
BOD5	50002	110	348	MG/L	0.78366	10.000	970.59	2080.00	3086.43	1476.80	3.03134	1.45044
BOD5	50003	550	365	MG/L	0.26837	15.984	74.28	809.36	211.41	87.22	2.94485	1.21489
BOD5	50003	130	364	MG/L	0.65735	230.000	2439.72	9733.00	5870.87	3123.66	2.37745	1.26495
BOD5	50004	100	356	LB/D	0.26331	699.978	5746.33	14119.99	12739.99	6642.17	2.19944	1.14671
BOD5	50004	410	356	MG/L	0.34867	0.839	4.65	19.65	16.61	5.96	3.59315	1.29048
BOD5	50005	460	366	MG/L	0.65670	16.000	77.83	660.00	253.23	104.56	3.39913	1.40346
BOD5	50005	100	366	MG/L	0.29684	566.000	2621.21	5876.00	6690.02	3130.79	2.52927	1.18365
BOD5	50006	510	52	MG/L	0.59595	5.000	15.87	41.00	45.87	20.70	2.89946	1.30885
BOD5	50006	100	52	MG/L	0.59595	180.000	1970.67	4400.00	8419.25	2998.61	4.04568	1.44091
BOD5	50007	530	336	MG/L	0.71272	2.600	10.01	53.00	34.30	14.13	3.55739	1.46534
BOD5	50007	510	159	MG/L	0.64379	5.000	25.80	86.40	75.83	34.57	2.93043	1.33569
BOD5	50007	410	228	MG/L	0.75653	3.000	20.09	81.60	62.42	29.07	3.07672	1.43263
BOD5	50007	100	339	MG/L	0.39952	140.000	1215.37	2940.00	2804.27	1441.86	2.29497	1.17999
BOD5	50008	410	51	MG/L	0.59595	0.930	6.68	29.75	34.31	10.18	5.31513	1.57758
BOD5	50008	100	48	MG/L	0.59595	49.200	323.21	857.14	1213.21	465.14	3.64091	1.39590
BOD5	50009	600	97	MG/L	0.57677	5.000	45.54	219.00	225.37	70.06	4.88115	1.51730
BOD5	50009	078	82	MG/L	0.64445	8.000	311.20	2400.00	3400.12	771.81	9.75144	2.21353
BOD5	50009	075	88	MG/L	0.59118	117.000	3347.69	40800.00	18669.80	5229.95	5.80489	1.62612
BOD5	50009	015	79	MG/L	0.27352	826.000	41656.99	452200.00	242945.74	61289.07	5.68398	1.43392
BOD5	50011	410	42	MG/L	0.59595	1.000	7.70	26.00	38.78	12.28	4.80999	1.52354

Table 4. BOD, COD, and TSS 1- and 30-day variabliity factors Adjusted for autocorrelation

ANALYTE	FACILITY CODE	SAMPLE SITE	NO. OF OBS.	UNIT	LAG-1 AUTO CORRELATION	MIN. DETECT	SAMPLE MEAN	SAMPLE MAX.	DAILY LIMITATION	30 DAY LIMITATION	DAILY VF	30 DAY VF
BOD5	50011	140	41	MG/L	0.59595	92.00	258.80	1100.00	724.47	333.44	2.8233	1.29941
BOD5	50012	540	21	MG/L	0.59595	0.40	2.51	9.40	11.33	3.74	4.5222	1.49266
BOD5	50012	100	24	MG/L	0.59595	0.40	143.84	373.00	4123.02	894.36	11.7601	2.55099
BOD5	50013	520	67	MG/L	0.47187	21.00	187.18	753.00	908.54	275.62	4.7533	1.44198
BOD5	50013	110	99	MG/L	0.62230	105.00	3413.25	5910.00	8568.49	4447.56	2.4222	1.25728
COD	12053	E	52	MG/L	0.66556	8.00	79.52	226.00	263.88	112.63	3.2595	1.39123
COD	12053	E	51	PPD	0.45046	1.36	11.69	33.75	38.68	15.30	3.2682	1.29322
COD	12317	E	248	MG/L	0.77814	2.00	16.65	62.00	57.22	25.29	3.4056	1.50544
COD	50001	600	362	MG/L	0.58011	65.00	150.86	665.00	303.54	178.39	2.0184	1.18619
COD	50001	200	363	MG/L	0.29984	95.00	1671.42	17400.00	6943.86	2214.45	4.1419	1.32088
COD	50002	410	359	MG/L	0.91044	58.00	374.03	1006.00	1150.00	620.95	3.0401	1.64150
COD	50002	110	359	MG/L	0.90209	157.00	2031.80	3750.00	6111.73	3347.96	2.9056	1.59167
COD	50003	550	365	MG/L	0.33776	196.80	744.23	10080.18	1693.23	836.95	2.3812	1.17702
COD	50003	130	365	MG/L	0.76498	526.00	4961.02	11980.00	11808.71	6638.76	2.3387	1.31481
COD	50004	100	50	LB/D	0.50951	1449.98	9192.68	13999.99	23447.06	11548.25	2.4959	1.22930
COD	50004	410	51	MG/L	0.50951	27.86	98.27	189.01	201.60	115.72	2.0433	1.17286
COD	50005	460	366	MG/L	0.54317	108.00	883.40	1702.00	1676.92	1029.45	1.8870	1.15842
COD	50005	100	365	MG/L	0.26379	986.00	5278.92	11583.00	12496.82	6174.14	2.3502	1.16115
COD	50006	510	52	MG/L	0.50951	7.00	93.62	214.00	372.48	136.04	3.7293	1.36200
COD	50006	100	52	MG/L	0.50951	151.00	2283.48	5875.00	13481.39	3857.85	5.2906	1.51395
COD	50007	530	614	MG/L	0.90370	72.00	369.65	1119.00	730.70	500.92	1.9714	1.35146
COD	50007	510	5	MG/L	0.50951	260.00	353.80	470.00	568.35	394.28	1.5994	1.10952
COD	50007	410	605	MG/L	0.87151	108.00	415.95	1156.00	780.57	537.52	1.8764	1.29213
COD	50007	100	682	MG/L	0.31155	436.00	3424.63	28200.00	7835.40	3970.92	2.2966	1.16390
COD	50008	410	63	MG/L	0.61282	3.00	17.06	70.00	60.19	23.91	3.4964	1.38881
COD	50008	100	70	MG/L	0.22158	126.00	761.65	1583.00	2554.51	965.24	3.2560	1.23033

Table 4. BOD, COD, and TSS 1- and 30-day variabliity factors
Adjusted for autocorrelation

ANALYTE	FACILITY CODE	SAMPLE SITE	NO. OF OBS.	UNIT	LAG-1 AUTO CORRELATION	MIN. DETECT	SAMPLE MEAN	SAMPLE MAX.	DAILY LIMITATION	30 DAY LIMITATION	DAILY VF	30 DAY VF
COD	50009	600	345	MG/L	0.83209	74.00	267.82	822.00	769.70	395.14	2.87356	1.47519
COD	50009	078	93	MG/L	0.88799	51.00	754.65	7800.00	4590.88	1637.15	6.35599	2.26661
COD	50009	075	218	MG/L	0.63628	351.00	5388.32	27600.00	26316.54	8485.32	4.83076	1.55760
COD	50009	015	191	MG/L	0.19172	258.00	64425.75	304000.00	429227.31	105018.78	5.77204	1.41224
COD	50011	410	38	MG/L	0.50951	20.00	74.61	260.00	229.77	95.79	3.11487	1.29856
COD	50011	140	39	MG/L	0.50951	240.00	548.21	1100.00	1219.69	657.07	2.21929	1.19557
COD	50012	540	21	MG/L	0.50951	7.00	24.60	69.30	88.45	33.40	3.56248	1.34514
COD	50012	100	24	MG/L	0.50951	56.40	256.23	462.30	775.01	336.73	2.94708	1.28045
COD	50013	520	68	MG/L	0.50951	250.00	1674.26	3500.00	4033.85	2062.04	2.37694	1.21506
COD	50813	110	163	MG/L	0.56933	1500.00	10838.18	19750.00	19493.77	12522.71	1.78875	1.14909
TSS	12053	E	84	MG/L	0.37161	0.40	6.84	35.00	36.38	10.06	5.17731	1.43214
TSS	12053	E	84	PPD	0.43463	0.06	1.03	5.26	5.54	1.55	5.25428	1.46848
TSS	12317	E	248	MG/L	0.77685	1.00	5.87	41.00	32.20	10.38	5.73826	1.84927
TSS	50001	600	362	MG/L	0.62560	12.00	63.21	240.00	204.34	86.29	3.23015	1.36402
TSS	50002	410	107	MG/L	0.18041	8.00	101.55	604.00	469.17	137.96	4.45756	1.31078
TSS	50003	550	365	MG/L	0.38215	16.34	154.62	2713.58	555.22	194.87	3.74424	1.31418
TSS	50004	410	356	MG/L	0.54391	0.49	18.69	254.40	91.47	27.27	5.08399	1.51567
TSS	50005	460	366	MG/L	0.62213	8.00	105.84	577.00	385.07	148.84	3.65529	1.41291
TSS	50006	510	52	MG/L	0.55093	1.00	37.92	198.00	259.75	67.41	6.36306	1.65139
TSS	50007	530	673	MG/L	0.59907	2.00	11.85	60.00	36.76	15.85	3.09294	1.33381
TSS	50007	510	462	MG/L	0.75337	4.00	24.19	110.00	58.98	32.03	2.44095	1.32549
TSS	50007	410	951	MG/L	0.77547	4.00	30.37	158.00	87.25	43.08	2.86584	1.41502
TSS	50007	100	783	MG/L	0.55539	24.00	655.19	40434.00	2803.97	879.34	4.74914	1.48936
TSS	50008	410	51	MG/L	0.55093	1.00	7.67	41.50	39.83	11.94	5.06212	1.51815
TSS	50008	100	48	MG/L	0.55093	48.00	213.81	672.00	678.87	284.64	3.14374	1.31813
TSS	50009	600	346	MG/L	0.39694	1.00	11.93	95.00	53.67	16.84	4.38053	1.37483

Table 4. BOD, COD, and TSS 1- and 30-day variabliity factors Adjusted for autocorrelation

ANALYTE	FACILITY CODE	SAMPLE SITE	NO. OF OBS.	UNIT	LAG-1 AUTO CORRELATION	MIN. DETECT	SAMPLE MEAN	SAMPLE MAX.	DAILY LIMITATION	30 DAY LIMITATION	DAILY VF	30 DAY VF
TSS	50009	078	216	MG/L	0.44561	3.0	152.60	6630.0	815.79	198.09	6.5741	1.59636
TSS	50009	075	231	MG/L	0.18427	8.6	166.49	11400.0	671.32	168.95	5.5282	1.39124
TSS	50009	015	172	MG/L	0.21235	2.0	769.59	11000.0	14686.27	2804.19	12.6528	2.41591
TSS	50011	410	42	MG/L	0.55093	5.0	28.38	120.0	119.41	41.16	4.1297	1.42339
TSS	50012	540	20	MG/L	0.55093	0.1	1.52	6.0	15.76	3.47	8.7639	1.93157
TSS	50012	100	24	MG/L	0.55093	2.4	31.58	129.5	266.83	62.18	7.7405	1.80366
TSS	50013	520	72	MG/L	0.98000	23.0	92.71	392.0	325.04	185.92	3.5311	2.01972
TSS	50013	110	230	MG/L	0.81082	208.0	2431.22	4342.0	4805.87	3109.81	1.9590	1.26765

2.3 Cyanide

A beta rather than a delta-lognormal distribution was used to model cyanide effluent data. The technology basis for cyanide treatment requires the reprocessing of wastewater if effluent concentrations exceed 1 ppm. This constraint on the maximum actual cyanide concentration that can occur requires that the statistical model fit to the cyanide data also have a maximum value; this property is true of the beta but not the delta-lognormal distribution. The parameters of the beta distribution were estimated from the cyanide dataset by the method of moments[5]. Parameter estimates were then substituted in the beta distribution from which the daily limitation (99th percentile) was calculated. The four-day cyanide limitation was estimated in a similar fashion.

Beta model for cyanide limitations

The beta density function with parameters a and b is expressed as follows:

$$\beta(x,a,b) = \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)} x^{a-1} (1-x)^{b-1} \qquad (15)$$

These parameters are related to the mean μ and variance σ^2 by the equations

$$a = \frac{\mu^2(1-\mu)}{\sigma^2} - \mu \qquad (16)$$

and

$$b = \frac{\mu(1-\mu)^2}{\sigma^2} + \mu - 1 \qquad (17)$$

[5]Wasan, M.T. 1974. *Parametric Estimation*. McGraw-Hill, New York. p. 5

The method of moments was used to estimate the parameters of this model. Sample estimates of the mean and variance were computed from the data with the nondetects set to the detection limit. These estimates were substituted for μ and σ^2 in the right-hand side of the above equations, yielding estimates of a and b. The estimated a and b were substituted into the expression for the beta density which was then numerically integrated to estimate the 99th percentile, or the daily limitation.

To estimate the 4-day limitation, the 95th percentile of 4-day means, it was assumed that 4-day means of beta random variables could be approximated by a beta random variable. The method of moments was then used as before to estimate parameters and percentiles. The moments are readily available since the 4-day mean is equal to the 1-day mean, and the 4-day variance is one-fourth the 1-day variance. In fact, sums of beta random variables are not exactly beta distributed, and as a check on the validity of the approximation assumption, a computer simulation approach was adopted to model the distribution of the average of four beta random variables. Limitations derived by these two alternative methods agreed within 2%, indicating that the assumption yields a reasonably close approximation to the percentiles of the true distribution. The estimated long-term mean, variability factors, and limitations for cyanide destruction are as follows:

Long-term mean (mg/L)	1-day VF	4-day VF	1-day limit (mg/L)	4-day limit (mg/L)
0.235	3.252	1.7245	0.766	0.406

3. Limitations and long-term means for specific treatment technologies

3.1 Treatment technologies for Ammonia and Priority and Nonconventional Organic Pollutants

The previous sections described how facility-level variability factors (VFs) were estimated from daily effluent concentration data using the modified delta-lognormal model. In this section we describe how these facility-level VFs were used to estimate daily and monthly average limitations for selected treatment technologies.

Each treatment technology was represented by a set of facility-level datasets consisting of daily effluent concentration measurements on a range of different constituents. The daily limitation and

monthly average limitation for a given constituent was estimated according to the following methodology:

- The long-term mean (LTM) was estimated for each facility dataset by computing the arithmetic average of the constituent daily concentrations. Observations below the method detection limit (DL) were set equal to the DL for the purposes of this calculation.

- The constituent LTM was defined to be the median of the facility-level constituent LTMs.

- For those facility datasets that had at least three detected values, the modified delta-lognormal model was used to estimate daily and monthly average variability factors (VF) as described above.

- The constituent daily VF was defined to be the median of the facility-level daily VFs; the constituent monthly average VF was defined to be the median of the facility-level monthly average VFs.

- The daily and monthly average limitations were calculated by multiplying the constituent LTM by the daily and monthly constituent VFs, respectively.

- A VF was transferred if it could not be directly estimated because of insufficient data; the transferred VF was defined to be the median of the other organic constituent VFs.

Tables 5 through 8 show the results of applying this methodology to estimate option long-term means and limitations for advanced biological treatment, in-plant steam stripping, in-plant steam stripping with distillation, and air stripping of ammonia.

Table 5. Long-term means and limitations
Advanced biological treatment

Analyte	Unit	Number of Facilities	Sample Long-Term Mean	Daily VF	Daily Limit	4 Day VF	4 Day Limit	Transfer VFs From Option
ACETONE	UG/L	4	113.20	3.6478	412.93	1.56822	177.52	
ACETONITRILE	UG/L	1	5.00	3.9789	19.89	1.69170	8.46	Y
AMMONIA	MG/L	1	2.56	1.8938	4.84	1.26333	3.23	
BENZENE	UG/L	6	10.00	3.9789	39.79	1.69170	16.92	Y
CARBON TETRACHLORIDE	UG/L	1	0.01	3.9789	0.04	1.69170	0.02	Y
CHLOROBENZENE	UG/L	1	10.00	3.9789	39.79	1.69170	16.92	Y
CHLOROFORM	UG/L	9	10.00	2.2069	22.07	1.32405	13.24	
CHLOROMETHANE	UG/L	2	51.70	3.9789	205.71	1.69170	87.46	Y
ETHANOL	UG/L	3	1001.50	2.4707	2474.43	1.34036	1342.37	
ETHYL ACETATE	UG/L	2	755.00	3.9789	3004.04	1.69170	1277.23	Y
FORMALDEHYDE	UG/L	1	343.33	4.3100	1479.76	1.81518	623.21	
HEPTANE	UG/L	1	5.00	3.9789	19.89	1.69170	8.46	Y
HEXANE	UG/L	1	5.00	3.9789	19.89	1.69170	8.46	Y
ISOPROPANOL	UG/L	2	281.25	3.9789	1119.06	1.69170	475.79	Y
ISOPROPYL ACETATE	UG/L	1	500.00	3.9789	1989.43	1.69170	845.85	Y
METHANOL	UG/L	3	1000.00	6.6575	6657.48	2.33730	2337.30	
METHYLENE CHLORIDE	UG/L	8	89.12	15.9195	1418.79	4.00916	357.31	
N-BUTANOL	UG/L	1	250.00	3.9789	994.72	1.69170	422.92	Y
N,N-DIMETHYLFORMAMID	UG/L	1	11.25	3.9789	44.76	1.69170	19.03	Y
PHENOL	UG/L	3	10.00	2.4959	24.96	1.37214	13.72	
PYRIDINE	UG/L	1	10.00	3.9789	39.79	1.69170	16.92	Y
TETRAHYDROFURAN	UG/L	1	1222.95	12.2719	15007.93	3.55499	4347.58	
TOLUENE	UG/L	9	10.00	3.9789	39.79	1.69170	16.92	Y
TRICHLOROFLUOROMETHA	UG/L	2	219.13	2.7344	599.18	1.46762	321.59	

Table 5. Long-term means and limitations
Advanced biological treatment

Analyte	Unit	Number of Facilities	Sample Long-Term Mean	Daily VF	Daily Limit	4 Day VF	4 Day Limit	Transfer VFs From Option
TRIETHYLAMINE	UG/L	1	50.00	3.9789	198.94	1.69170	84.58	Y
XYLENES	UG/L	2	10.00	3.9789	39.79	1.69170	16.92	Y
1,2-DICHLOROETHANE	UG/L	3	64.16	6.8272	438.02	2.36887	151.98	
1,4-DICHLOROBENZENE	UG/L	1	1.00	3.9789	3.98	1.69170	1.69	Y
1,4-DIOXANE	UG/L	1	55.30	3.9789	220.03	1.69170	93.55	Y
2-BUTANONE	UG/L	1	50.79	3.9789	202.08	1.69170	85.92	Y
2-METHYLPYRIDINE	UG/L	1	50.00	3.9789	198.94	1.69170	84.58	Y
4-METHYL-2-PENTANONE	UG/L	2	30.00	3.9789	119.37	1.69170	50.75	Y

Table 6. Long-term means and limitations
In-Plant Steam Stripping

Analyte	Unit	Number of Facilities	Sample Long-Term Mean	Daily VF	Daily Limit	4 Day VF	4 Day Limit	Transfer VFs From Option
CHLOROFORM	UG/L	2	10.00	7.9533	79.53	2.68207	26.82	Y
ETHANOL	UG/L	2	350801.26	6.2700	2199509.27	2.23432	783803.01	
ISOPROPANOL	UG/L	2	76305.55	7.8204	596741.52	2.60071	198448.39	
METHANOL	UG/L	3	1374000.00	8.4810	11652951.31	2.76344	3796967.47	
METHYLENE CHLORIDE	UG/L	3	100.04	8.0863	808.98	2.78545	278.67	
PYRIDINE	UG/L	1	1000.00	7.9533	7953.34	2.68207	2682.07	Y
TETRAHYDROFURAN	UG/L	1	1542.00	5.9701	9205.93	2.18155	3363.95	
TOLUENE	UG/L	5	100.00	1.9807	198.07	1.48040	148.04	
2-BUTANONE (MEK)	UG/L	1	121237.91	11.8742	1439606.92	3.54418	429689.10	
2-PROPANONE (ACETONE)	UG/L	1	3000.38	10.4546	31367.78	3.23076	9693.50	

Table 7. Long-term means and limitations
In-Plant Steam Stripping with Distillation

Analyte	Unit	Number of Facilities	Sample Long-Term Mean	Daily VF	Daily Limit	4 Day VF	4 Day Limit	Transfer VFs From Option
CHLOROFORM	UG/L	2	10.00	5.72424	57.24	2.12315	21.23	Y
METHANOL	UG/L	1	1518.46	5.47835	8318.67	2.06475	3135.24	
METHYLENE CHLORIDE	UG/L	3	100.04	8.08626	808.98	2.78545	278.67	
PYRIDINE	UG/L	1	1000.00	5.72424	5724.24	2.12315	2123.15	Y
TETRAHYDROFURAN	UG/L	1	1542.00	5.97012	9205.93	2.18155	3363.95	
TOLUENE	UG/L	5	100.00	1.83647	183.65	1.34534	134.53	
2-BUTANONE (MEK)	UG/L	1	25812.71	6.24302	161149.21	2.24305	57899.11	
2-PROPANONE (ACETONE)	UG/L	1	388.88	3.06842	1193.23	1.54190	599.61	

Table 8. BAT long-term means and limitations
Ammonia Air Stripping

Analyte	Unit	Number of Facilities	Sample Long-Term Mean	Daily VF	Daily Limit	4 Day VF	4 Day Limit
AMMONIA	MG/L	1	9.91429	1.30544	12.9425	1.09986	10.9044

3.2 Advanced Biological Treatment of BOD, COD, and TSS

The limitations and variability factors for BOD, COD, and TSS based on advanced biological treatment are shown in Table 7 for subcategory A and C, and in Table 8 for subcategory B and D. They were derived by taking the arithmetic averages of limitations and variability factors of BPT facility datasets that represent treated effluent from advanced biological treatment, selected from Table 4 (the facility codes are listed in the first column). For example, Table 8 gives the 1-day BOD limitation for subcategory B and D as 36.55 mg/L, which is the mean of the values 34.31 mg/L for facility 500018-410 and 38.78 mg/L for facility 50011-410 as shown in Table 3.

Table 9. BPT limitations and variability factors, Subcategory A and C

Plant Stream	BOD				COD				TSS			
	Limitation (mg/l)		Variability Factor		Limitation (mg/l)		Variability Factor		Limitation (mg/l)		Variability Factor	
	1-day	30-day	1-day	30-day	1-day	30-day	1-day	30-day	1-day	30-day	1-day	30-day
50002 410	143.41	62.32	3.52	1.53	1150.00	620.95	3.04	1.64	469.17	137.96	4.46	1.31
50003 550	211.41	87.22	2.94	1.21	1693.23	836.95	2.38	1.18	555.22	194.87	3.74	1.31
50004 410	16.61	5.96	3.59	1.29	201.60	115.72	2.04	1.17	91.47	27.27	5.08	1.52
50005 460	253.23	104.56	3.40	1.40	1676.92	1029.45	1.89	1.16	385.07	148.84	3.66	1.41
50007 410	62.42	29.07	3.08	1.43	780.57	537.52	1.88	1.29	87.25	43.08	2.87	1.42
Mean Value	137.42	57.83	3.31	1.37	1100.46	628.12	2.25	1.29	317.64	110.40	3.96	1.39

Table 10. BPT limitations and variability factors, Subcategory B and D

Plant Stream	BOD				COD				TSS			
	Limitation (mg/l)		Variability Factor		Limitation (mg/l)		Variability Factor		Limitation (mg/l)		Variability Factor	
	1-day	30-day	1-day	30-day	1-day	30-day	1-day	30-day	1-day	30-day	1-day	30-day
50008* 410	34.31	10.18	5.32	1.58	60.19	23.91	3.50	1.39	39.83	11.94	5.06	1.52
50011* 410	38.78	12.28	4.81	1.52	229.77	95.79	3.11	1.30	119.41	41.16	4.13	1.42
Mean Value	36.55	11.23	5.07	1.55	144.98	59.85	3.31	1.35	79.62	26.55	4.60	1.47

* Insufficient number of adjacent day observations to compute plant-specific lag-1 autocorrelation; average value of correlation is assumed.