Memorandum





Date:	October 22, 2018
То:	Buckman Direct Diversion Board
From:	Michael Dozier, BDD Operations Superintendent
Subject:	Update on BDD Operations for the Month of October 2018

ITEM:

- 1. This memorandum is to update the Buckman Direct Diversion Board (BDDB) on BDD operations during the month of October 2018. The BDD diversions and deliveries have averaged, in Million Gallons Per Day (MGD) as follows:
 - a. Raw water diversions: 5.66 MGD
 - b. Drinking water deliveries through Booster Station 4A/5A: 5.08 MGD
 - c. Raw water delivery to Las Campanas at BS2A: 0.53 MGD
 - d. Onsite treated and non-treated water storage: 0.05 MGD Average
- 2. The BDD is providing approximately 81% percent of the water supply to the City and County for the month.
- 3. The BDD year-to-date diversions are depicted below:



Year-To-Date Comparison



4. Background Diversion tables:

Buckman Direct Diversion Monthly SJC and Native Diversions

Oct-18				In Acre-F	eet		
Month	Total SJC + Native Rights	SP-4842 RG Native COUNTY	SD-03418 RG Native LAS CAMPANAS	<mark>SJC Call</mark> Total	SP-2847-E SJC Call CITY	SP-2847-N-A <mark>SJC Call</mark> LAS CAMPANAS	All Partners Conveyance Losses
JAN	380.137	77.791	0.000	302.346	302.346	0.000	3.023
FEB	336.287	66.413	0.000	269.874	269.874	0.000	2.699
MAR	362.730	266.898	0.000	95.832	95.832	0.000	0.958
APR	661.333	568.669	0.000	92.664	92.664	0.000	0.927
MAY	933.072	340.260	0.000	592.812	481.647	111.165	5.928
JUN	873.384	44.160	0.000	829.224	693.960	135.264	8.292
JUL	807.939	0.000	0.000	807.939	719.953	87.986	11.277
AUG	731.455	61.799	0.000	669.656	669.656	0.000	6.697
SEP	741.437	54.635	0.000	686.803	686.803	0.000	6.868
ОСТ	328.370	59.090	0.000	269.280	262.741	6.539	2.693
NOV	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DEC	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	6,156.143	1,539.714	0.000	4,616.429	4,275.475	340.954	49.362

In Million Gallons (MG)

Month	Native COUNTY	Native Las Campanas	<mark>SJC</mark> TOTAL	SJC CITY	SJC Las Campanas	All Partners Diversions BDD
JAN	28.160	0.000	98.565	98.565	0.000	126.725
FEB	21.651	0.000	87.979	87.979	0.000	109.629
MAR	96.617	0.000	31.241	31.241	0.000	127.858
APR	185.386	0.000	30.208	30.208	0.000	215.595
MAY	123.174	0.000	193.257	157.017	36.240	316.431
JUN	14.396	0.000	270.327	226.231	44.096	284.723
JUL	0.000	0.000	263.388	234.705	28.684	263.388
AUG	20.147	0.000	218.308	218.308	0.000	238.454
SEP	19.778	0.000	223.898	223.898	0.000	243.675
OCT	19.263	0.000	87.785	85.654	2.132	107.049
NOV	0.000	0.000	0.000	0.000	0.000	0.000
DEC	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	528.572	0.000	1,504.956	1,393.805	111.151	2,033.528

			Total SJC		Las	Total		
			Available	CITY	Campanas	Native Rio	Total BDD	SJC used
	Total SJC	Convey-	at BDD	Total SJC	Total SJC	Grande	Surface	to offset
	Release	ance Losses	Diversion	Diversion	Diversion	Diversion	Diversion	Buckman
Month	(Ac-ff)	(Ac-ff)	(Ac-ft)	(Ac-ft)	(Ac-ff)	(Ac-ft)	(Ac-ft)	Wells
JAN	328.16	3.03	325.13	325.13		50.54	375.67	
FEB	248.93	2.29	246.65	246.65		77.48	324.13	
MAR	459.31	4.26	455.05	455.05		128.55	583.60	
APR	562.55	5.04	557.51	557.51		145.95	703.46	
MAY	407.82	3.63	404.19	404.19		179.69	583.88	
JUN	291.83	2.66	289.17	191.31	97.86	34.26	323.43	
JUL	360.03	3.26	356.77	251.89	104.87	113.93	470.69	
AUG	133.52	1.22	132.30	88.75	43.55	67.55	199.85	
SEP	313.61	2.52	311.09	311.09		316.73	627.82	
OCT	585.70	4.23	581.47	563.60	17.88	149.97	731.45	
NOV	288.72	2.58	286.14	282.09	4.05	122.83	408.97	
DEC	277.86	2.22	275.64	275.64		109.01	384.65	
TOTALS	4,258.04	36.94	4,221.11	3,952.90	268.21	1,496.49	5,717.60	

2016 Buckman Direct Diversion Monthly SJC and Native Diversions

Source of SJC Releases in reporting month. Includes conveyance losses.

2016			ABIQUIU	
	Total			Club at
	Release			Las
Month	(Ac-ft)	City	County	Campanas
JAN	328.16	328.16		
FEB	248.93	248.93		
MAR	459.31	459.31		
APR	562.55	562.55		
MAY	407.82	407.82		
JUN	291.83	193.07		98.76
JUL	360.03	254.20		105.83
AUG	133.52	89.57		43.95
SEP	313.61	313.61		
OCT	585.70	567.69		18.01
NOV	288.71	284.63		4.08
DEC	277.86	277.86		
TOTALS	4,258.03	3,987.40		270.63

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			Total SJC		Las	Total	
			Available	CITY	Campanas	Native Rio	Total BDD
	Total SJC	Convey-	at BDD	Total SJC	Total SJC	Grande	Surface
	Release	ance Losses	Diversion	Diversion	Diversion	Diversion	Diversion
Month	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ff)	(Ac-ft)
JAN	246.57	2.40	244.17	244.17		66.12	310.29
FEB	272.15	2.36	269.79	269.79		56.73	326.52
MAR	180.19	1.60	178.59	178.59		178.02	356.61
APR	0.00	0.00	0.00	0.00		40.13	40.13
MAY	226.67	2.15	224.53	224.53		238.73	463.26
JUN	563.77	5.04	558.72	448.40	110.33	128.54	687.27
JUL	299.65	2.70	296.95	234.93	62.02	148.67	445.62
AUG	279.43	2.54	276.89	276.89		213.73	490.62
SEP	552.16	4.98	547.18	547.18		130.85	678.03
OCT	597.48	5.30	592.18	592.18		80.41	672.59
NOV	428.42	3.89	424.52	424.52		66.27	490.79
DEC	197.65	1.76	195.89	195.89		111.20	307.09
TOTALS	3,844.14	34.72	3,809.41	3,637.07	172.35	1,459.40	5,268.82

2015 Buckman Direct Diversion Monthly SJC and Native Diversions

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Source of SJC Releases in reporting month. Includes conveyance losses.

2015			ABIQUIU	
	Total			Club at
	Release			Las
Month	(Ac-ft)	City	County	Campanas
JAN	246.57	246.57		
FEB	272.15	272.15		
MAR	180.19	180.19		
APR	0.00	0		
MAY	226.67	226.67		
JUN	563.76	452.44		111.32
JUL	299.65	237.07		62.58
AUG	279.43	279.43		
SEP	552.16	552.16		
OCT	597.48	597.48		
NOV	428.42	428.42		
DEC	197.65	197.65		
TOTALS	3,844.13	3,670.23		173.90

			Total SJC			Total		
			Available	CITY	COUNTY	Native Rio	Total BDD	SJC used
	Total SJC	Convey-	at BDD	Total SJC	Total SJC	Grande	Surface	to offset
	Release	ance Losses	Diversion	Diversion	Diversion	Diversion	Diversion	Buckman
Month	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ff)	(Ac-ft)	(Ac-ft)	Wells
JAN	383.35	3.74	390.34	390.34		12.68	403.02	
FEB	349.51	3.28	341.55	341.55		11.38	352.93	
MAR	373.88	3.66	381.69	357.07	34.09	148.83	539.99	
APR	178.75	1.70	176.78	92.46	84.47	227.22	404.15	
MAY	491.46	4.61	480.35	389.13	91.22	374.86	855.21	
JUN	427.50	3.96	412.65	295.07	117.58	292.84	705.49	
JUL	425.22	4.14	431.96	399.51	32.46	72.32	504.29	
AUG	496.68	4.60	479.66	479.66		96.07	575.73	
SEP	552.71	5.40	562.83	562,83		84.85	647.68	
OCT	381.93	3.63	378.30	378.30		142.46	520.76	
NOV	441.14	4.09	426.17	426.17		11.59	437.76	
DEC	423.99	4,13	430.74	430.74		19.56	450.30	
TOTALS	4,926.12	46.94	4,893.02	4,542.83	359.82	1,494.66	6,397.31	

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2014 Buckman Direct Diversion Monthly SJC and Native Diversions

Source of SJC Releases	in reporting month.	Includes conveyance losses.
		J

2014		,	ABIQUIU	
	Total			Club at
	Release			Las
Month	(Ac-ft)	City	County	Campanas
JAN	383.35	383.35		
FEB	349.51	349.51		
MAR	373.74	346.37		27.37
APR	178.83	93.42		85.41
MAY	491.82	399.41		92.41
JUN	427.82	307.54		120.28
JUL	425.22	397.13		28.09
AUG	496.68	496.68		
SEP	552.71	552.71		
OCT	381.93	381.93		
NOV	441.14	441.14		
DEC	423.99	423.99		
TOTALS	4,926.74	4,573.18		353.56

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			Total SJC		n an	Total		
			Available	CITY	COUNTY	Native Rio	Total BDD	SJC used
	Total SJC	Convey-	at BDD	Total SJC	Total SJC	Grande	Surface	to offset
	Release	ance Losses	Diversion	Diversion	Diversion	Diversion	Diversion	Buckman
Month	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	Wells
JAN	439.04	4.24	441.79	441.79		44.09	485.88	
FEB	261.03	2.47	257.94	257.94		10.49	268.43	
MAR	353.69	3.30	343.57	343.57		75.66	419.23	
APR	680.73	6.34	661.33	661.33		89.47	750.80	
MAY	1,045.27	9.88	1,030.46	1030.46		22.86	1,053.32	
JUN	817.91	7.85	734.56	734.56	83.44	260.03	1,078.03	
JJL	606.85	5.90	397.47	397.47	78.83		476.30	138.43
AUG	108.68	0.91	41.68	41.68	36.91		78.59	16.46
SEP	136.77	1.43	63.86	63.86	53.76		117.62	31.68
OCT	255.24	2.46	213.87	213.87	42.66	72.92	329.45	
NOV	196.45	1.88	187.02	187.02	8.48	117.33	312.83	
DEC	293.76	2.63	274.19	274.19		12.25	286.44	
TOTALS	5,195.42	49.29	4,647.74	4,647.74	304.08	705.10	5,656.92	186.57

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2013 Buckman Direct Diversion Monthly SJC and Native Diversions

Source of SJC Releases in reporting month. Includes conveyance losses.

2013			ABIQUIU	
	Total			Club at
	Release			Las
Month	(Ac-ft)	City	County	Campanas
JAN	439.04	439.04		
FEB	261.03	261.03		
MAR	353.69	353.69		
APR	680,73	680.73		
MAY	1,045.27	1045.27		
JUN	817.90	729.3		88.6
JUL	606.85	473.27		133.58
AUG	108.68	65.21		43.47
SEP	136.77	83.87		52.9
OCT	255.24	211.15		44.09
NOV	196.46	186.31		10.15
DEC	293.76	293.76		
TOTALS	5,195.42	4,822.63		372.79

		an a	Total SJC		Total	2.2461.2557.25577.25577.25577	
			Available		Native Rio	Total BDD	SJC used
	Total SJC	Convey-	at BDD	Total SJC	Grande	Surface	to offset
	Release	ance Losses	Diversion	Diversion	Diversion	Diversion	Buckman
Month	(Ac-ff)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	(Ac-ft)	Wells
JAN	448.09	4.06	447.00	411.56	5.02	416.58	35.44
FEB	210.29	1.97	216.94	208.13	32.21	240.34	8.81
MAR	335.75	2.94	323.61	312.85	59.21	372.06	10.76
APR	528.63	4.72	519.90	519.90	108.61	628.51	
MAY	660.18	6.24	651.05	651.05	145.51	796.56	
JUN	722.36	6.79	692.21	692.21	120.92	813.13	
JUL	152.03	2.23	191.75	157.16		157.16	34.60
AUG	86.08	0.58	60.90	60.90	239.96	300.86	
SEP	637.17	6.05	630.92	630.92	110.07	740.99	
ОСТ	747.21	7.14	744.87	744.87	50.82	795.69	
NOV	479.19	4.63	482.65	482.65	120.91	603.56	
DEC	442.67	4.17	434.71	434.71	119.44	554.15	
TOTALS	5,449.65	51.52	5,396.51	5,306.91	1,112.68	6,419.59	89.61

2012 Buckman Direct Diversion Monthly SJC and Native Diversions

Source of SJC Releases in reporting month. Includes conveyance losses.

2012		HER	ON	EL VADO		ABIC	QUIU
	Total Release						
Month	(Ac-ft)	City	County	City	County	City	County
JAN	448.09					448.09	
FEB						210.29	
MAR						335.75	
APR						528.63	
MAY						660.18	
JUN			27.21			695.15	
JUL			21.42			130.61	
AUG						86.08	
SEP						637.17	
OCT						747.21	
NOV						479.19	
DEC						442.67	
TOTALS	448.09	[48.63			5,401.02	

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10/24/2018





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<u>The Removal Efficiency &</u> <u>Assessment of Treatments</u>

TREAT Study at Buckman Direct Diversion



Brief Report October 2018

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I. OBJECTIVE

The purpose of this study was to investigate the efficiency of the treatments at the Buckman Direct Diversion (BDD) with respect to contaminants that may occur in the Rio Grande upstream from the BDD, such as the Los Alamos Canyon Watershed. A similar study was conducted in 2012/2013 under the 2010 MOU BDDB/LANL financed by LANL. There have been other theoretical evaluations of the separate treatment technologies applied at BDD. Most of these technologies have been applied throughout the United States successfully to treat drinking water. BDD has not been an exception. Surface water diverted from the Rio Grande has been treated to all EPA standards since the facility opened in 2011.

The intent of this study, as described, was to practically confirm theoretical evaluations of the efficiency of the plant. The study was intended to be run during various seasons and under different source conditions (high turbidity vs. low turbidity), in an attempt to explore the limits of the treatment technologies at BDD.

II. BACKGROUND

To date there have been three attempts to evaluate the efficiency of the BDD treatments train:

1. The first attempt was a part of the CDM Smith (contractor for the BDD project) sampling during the 2005 Pilot Study. The Pilot Study's goal was not to determine the efficiency of removal of contaminants in the surface water, but to establish operational parameters for the plant. The results from the Pilot Study were inconclusive.

2. The second attempt to evaluate the efficiency of treatments was by Dr. Howe (Report dated April 15, 2008). There are a couple of problems with this report as listed below. Because of these problems, the conclusions of Dr. Howe's report could not be accepted with high confidence.

- The assumed concentrations of contaminants in the Rio Grande were inaccurate. The contaminant concentrations in the Rio Grande at BDD were chosen from locations that were not similar to the BDD Intake, either upstream from the contaminant source(s) which is the Los Alamos Canyon Watershed (LACW), or far downstream from BDD Intake and therefore at much diluted concentrations with respect to the LACW. After many years of regular storm water monitoring by different agencies, the available data for the Rio Grande at BDD is very limited and does not capture the complete Rio Grande contaminants profile.
- An assumption was made that filtering a sample of surface water would be equivalent to the treatment system installed at BDD. Therefore, when conclusions were made, the author adopted the efficiency of a 50-micrometer filter in order to determine treatment efficiency for specific contaminant as it would be applicable to the BDD treatments. No references to known protocols or scientific articles were offered to substantiate such approach.

3. The third attempt to evaluate the efficiency of the BDD treatments was the Contaminant Fate Analysis (CFA) that was conducted as part of the 2010 BDDB/LANL MOU from March 2012 until February 2013. The results from that study were also inconclusive. The shortcomings of that sampling design have been outlined in a separate report.

III. DESIGN OF TREAT

The design for TREAT was adopted from the design of a similar study. See reference in Section VI. The idea of the study was to sample the same volume of water as it passes through each treatment of the plant in order to compare the concentrations of chemicals (or contaminants) after each treatment process. By comparing the concentrations of each chemical before a treatment process and after the same treatment process, one can calculate the efficiency of that process as a simple percent removal. The intent was also to accomplish six (6) TREAT runs in order to understand the variation in efficiency throughout the seasons of the year.



Figure 1. Treatment processes at BDD.

A treatment diagram of the BDD is provided in Figure 1. At BDD, conventional and advanced treatment technologies are applied. The TREAT study investigated the concentrations of contaminants along the entire treatment train:

- 4 at the river (Sampling Station RG),
- before any treatment but after Lakos (Sampling Station 1),
- 4 after conventional treatment (Sampling Station 2),
- 4 after membranes filtration (Sampling Station 3), and
- after GACs (Sampling Station 4).

Each run of the TREAT study was conducted for four hours, during normal plant operations and during continuous treatment of the plant. Grab samples were collected every 30 minutes at each sampling station and at pre-determined times. Those grab samples were composited into one volume to simulate mixing of treated water throughout the treatment processes. To account for the seasonal variability of the source, TREAT runs (sampling events) were conducted at different times of the year. During each TREAT run the raw water pump rate and the treatment rate through the plant were kept constant.

The sampling at each station was lagged a specific amount of time calculated by BDD operations to account for the initial volume of water passing through the pipes, booster stations and treatment processes of the plant. This ensured that during the study the same volume of water was sampled for the entire duration of each run.

IV. SAMPLING STATIONS DESCRIPTION

Sample Station Rio Grande (RG) was located at the diversion. 24 liters of surface water sample was collected at once from approximately the top 2-3 feet of the river in front of the intake structure of cell 5.

Sample Station One (SS1) was located at the Booster Station 2A structure. The sample was taken from the wet well of the booster station pump in Booster Station 2A with a tap opened continuously during the sampling so flushing was not necessary when collecting 24 liters (3 liters every half hour for 4 hours.)

Sample Station Two (SS2) was located at the settled water analyzer station in the Membrane Feed pump area. The sample was collected at a calculated time lag after SS1. This tap is running constantly so flushing was not necessary when collecting the 24 liters sample (3 liters every half hour for 4 hours.)

Sample Station Three (SS3) was located at the Membrane Combined analyzer station. The sample was collected at a calculated time lag after SS2. This tap is running constantly, so flushing was not necessary before taking a sample. 24 liters were collected as at SS1 and SS2.

Sample Station Four (SS4) was located at the GAC combined turbidity analyzer station. The sample was collected at a calculated time lag after SS3. This tap is running constantly, so flushing was not necessary before taking a sample. 24 liters were collected as at the other sampling stations.

V. CONSTITUENTS TESTING

The collected samples from all four stations including sampling of the Rio Grande at the Diversion were tested for the following constituents. On rare occasions, when analyses of PCBs and drug residues were ordered, only some of the sampling stations were analyzed due to budget constraints.

Constituent	Analysis	Basis
Gross alpha/beta	EPA 900.0	SDWA, LACW
Strontium-90	ASTM 5811	SDWA, LACW
Tritium		LACW
Isotopic Uranium	HASL-300	LACW
Isotopic Plutonium	HASL-300	LACW
Americium-241	HASL-300	LACW
Gamma Spectroscopy	EPA 901.1	SDWA, LACW
Radium 226/228	EPA 903.1/904	SDWA, Historical Data
Metals Primary(F/UF)	EPA 200.7	SDWA, LACW

Table 1. Analytes and analytical methods selected for TREAT.

Constituent	Analysis	Basis
Metals Secondary (F/UF)	EPA 200.8	SDWA
Mercury	EPA 245.1	SDWA
Suspended Sediment Concentration	ASTM D3977-97	RG occurrence
Polychlorinated Biphenyls (PCBs)	EPA 1668A	LACW, RG occurrence
Nitrate/Nitrite	EPA 353.	RG occurrence
Sulfate	EPA 375.	RG occurrence
Total Organic Carbon	SW-846 9060	Process Control
Turbidity		RG, Process Control
Total Dissolved Solids	EPA 160.1	Process Control
Drug Residues		RG occurrence

Notes to Table:

SDWA is the Safe Drinking Water Act LACW is Los Alamos Canyon Watershed RG is the Rio Grande

VI. REFERENCES

Efficiency of conventional drinking-water-treatment processes in removal of pharmaceuticals and other organic compounds. **Stackelberg, Paul E., et al. 2007.** 377, s.l. : Elsevier, 2007, Science of the Total Environment, pp. 255-272.

VII. RESULTS

BDD conducted four sampling events of the TREAT study: March 2016 (run #1), May 2016 (run #2), September 2016 (run #3), and April 2017 (run #4). TREAT study run #4 was eliminated because the results suggested that the TREAT samples were contaminated during the process of collection and handling prior to being sent to the contract laboratory and/or a major lab error occurred in metals analysis performed by the contract laboratory. A subsequent metals' analysis by another contract laboratory were inconsistent with the first laboratory's results. This report presents the results from TREAT study run #1, run #2, and run #3. See Appendix.

Due to the large amount of data, the following decisions were made when presenting the data in the Appendix. The removal efficiency of the combined treatments at BDD was calculated in the last column of the tables.

1. All results from metals analyses, total and dissolved, and radionuclides were presented in the tables, whether detected or non-detected.

2. Only the detected radionuclides from gamma spectroscopy analysis were included in the table.

3. Only the results for Total PCBs were included.

4. In the Drug Residue groups, if there were any detects at any of the sampling stations, then the results were included in the tables. Otherwise, if the results for all sampling stations for a specific "drug residue" constituent were non-detect then that constituent was not included in the table, although analyzed.

5. Efficiency was calculated for total suspended sediment concentration (SSC), total metals, radionuclides, and organic chemicals (PCBs, "Drug Residues").

6. The efficiency was calculated as the concentration in the last station (SS4) was divided by the concentration in the first station (RG) or the second station (SS1) whichever was higher. If both of these values were non-detects then the denominator was the concentration in the third station (SS2).

7. When the concentration of the last sampling station (SS4) was non-detect (also marked with "<" sign), the efficiency carried ">" (greater than) sign. Otherwise, when the concentration was "detect", the efficiency did not carry any additional markings.

8. When all results in all sampling stations were non-detect, the efficiency was marked with "nd."

9. The efficiency of soluble or highly soluble chemicals was not calculated, and the efficiency was marked with "soluble" or "hi soluble."

10. The efficiency for dissolved metals was not calculated.

VIII. INTERPRETATION OF THE RESULTS

It was expected that the concentrations of the different contaminants in the source water would decrease after each treatment process at the plant is applied. The treatments at BDD remove mainly solid particles from the source water, thus only those contaminants with strong affinity toward solid particles would experience reduced concentrations after each treatment. The concentrations of chemicals with moderate or high solubility in water show little or no reduction by the treatments of the plant. Thus, in order to follow how effectively each treatment reduces the concentration of any given chemical, the reader can simply compare the results in adjacent columns starting at the very left and moving to the right. Effective removal is affirmed by lower concentrations at each right column in comparison to its neighboring left column.

Using the suggested interpretation described above, the data provides the following summarized conclusions:

1. BDD conducted its TREAT studies during early spring (run #1), middle of spring (run #2), and early fall (run #3). The concentrations of certain chemicals were the highest during run #3 and the detection limits of the contract laboratory were lower than the previous two sampling events. For this reason, the removal efficiencies during run #3 may be the most informative of the capability of the treatments.

2. The removal efficiency of solid particles at BDD is exceptionally good. That parameter was measured by the Suspended Sediment Concentration (SSC), and the efficiencies for all total SSC for all TREAT runs were greater than 97%. See Table 2.

Selected			
Chemicals	Mar-16	May-16	Sep-16
Al	> 96%	> 99%	> 99.5%
As	> 38%	> 47%	> 93%
Pb	> 81%	> 86%	> 91%
Mn	> 98%	> 99%	> 99.4%
U	> 74%	> 74%	6%
SSC	> 97%	> 98%	> 99.4%
Gross Alpha	> 35%	> 50%	> 73%
Gross Beta	> 60%	62%	52%
11 24	1	F.1 C 11	

Table 2. Treatment efficiency for selected contaminants.

">" means greater than [the following number]

- 3. The removal efficiency for all total metals that have low solubility in water and those with high affinity to solid particles, were removed very successfully by the treatments at BDD. See Table 2 and Appendix.
- 4. The treatment efficiency can only be measured with high confidence if the initial concentration of the contaminant is high and if the final concentration is not a "non-detect" value. The quality of the Rio Grande (the source water) is very good during base flow conditions and thus the initial concentrations of most contaminants were low or "non-detect." That is why many efficiency values were marked with "nd" (non-detect) and the efficiencies for those contaminants could not be calculated.
- 5. The first two TREAT sampling events were analyzed by a contract laboratory which did not have the ability to detect contaminants at low detection limits, and this fact limited the possible efficiency calculations.
- 6. The removal efficiency for the organic compounds selected for analysis varied from "no change" (no removal) to more than 94% removal. It should be noted that with the exception of PCBs, all of these compounds are unregulated compounds, "Drug Residues" category. See Table 3. The range of removal efficiency varies as each organic compound has different structure and a different affinity toward water and suspended sediment. However, the occurrence of these constituents in the Rio Grande is at very low concentrations (in the parts per trillion).

[Die	Davidation	After	After			Efficiency in
Date	Drug Residue	Unit	- RIO Crando	Kaw water	Conventional	Membrane	After GAC	Efficiency	Beforency in
			Grande	After Lakos	Treatment	Filter			Reference
	Androsterone	ng/L	< 51.9	47.7	227	< 48.1	< 28.2	> 40.9%	
	Mestranol	ng/L	118*	150*	97.8*	120*	101*	QC	
	Acetaminophen	ng/L	< 15.3	45.2	< 15.6	< 15.2	< 15.6	> 65.5%	98%
	Caffeine	ng/L	< 15.3	17.7	< 15.6	< 15.2	< 15.6	> 11.9%	88%
Mar-16	Sulfamethoxazole	ng/L	3.92	3.76	1.05	1.04	< 0.623	> 84.1%	100%
	Benzoylecgonine	ng/L	< 0.305	0.407	< 0.565	< 0.303	< 0.311	> 23.6%	
	Benztropine	ng/L	0.601	< 0.507	< 0.519	< 0.506	< 0.519	> 13.6%	
	Cocaine	ng/L	0.232	0.304	1.96	< 0.152	< 0.156	> 48.7%	
	DEET	ng/L	18.3	1.89	2.04	1.35	1.14	93.8%	35%
	Androstenedione	ng/L	< 2.07	< 2.10	< 2.10	2.38	< 2.10	nd	
								no	
	Desogestrel 3	ng/L	< 194	< 265	< 147	108	137	change	
May-16	Mestranol	ng/L	156*	213*	155*	143*	115*	QC	
	Caffeine	ng/L	88.7	38.6	< 15.7	< 17.3	< 15.8	> 82.2%	88%
	Sulfamethoxazole	ng/L	2.64	3.41	1.46	0.98	< 0.630	> 81.5%	100%
	1,7-								
	Dimethylxanthine	ng/L	68.6	< 63.1	< 62.9	< 69.1	< 63.0	> 8.2%	
	Amitriptyline	ng/L	0.320	< 0.316	< 0.315	< 0.345	< 0.315	> 1.6%	
	Benzoylecgonine	ng/L	0.414	< 0.316	< 0.315	< 0.345	< 0.315	> 23.9%	
	DEET	ng/L	19.0	4.83	3.01	5.09	4.19	> 77.9%	35%
	Theophylline	ng/L	73.0	< 63.1	< 62.9	< 69.1	< 63.0	> 13.7%	
	Triclosan	ng/L	< 52	68			< 53	> 22.1%	
	Caffeine	ng/L	< 2.1	26			9.4	63.8%	88%
	Sulfamethoxazole	ng/L	6.9	7.6			< 1.1	> 85.5%	100%
5 m 15	DEET	ng/L	130	25		الم م ما	10	92.3%	35%
Seb-10	Diclofenac	ng/L	15	< 2.1	notana	iiyzeo	< 2.1	> 86.0%	
	Oxybenzone	ng/L	100	24			< 21	> 79.0%	
	PCBs (total	anti	227	207			170	45 30/	
	congeners)	pg/r	327	297			1/9	45.5%	
	Caffeine	ng/L	5.2				1.3	75.0%	88%
	Carbamazepine	ng/L	0.45	1			< 0.35	> 22.2%	
NWED*	DEET	ng/L	2				1.7	15.0%	
	Dilantin	ng/L	0.34	1	not analyzed		0.22	35.3%	
2017	Salicylic Acid	ng/L	12				15	soluble	
	Atrazine	ng/L	0.014	1			0.00058	95.9%	

Table 3. Treatment efficiency for detected constituents in the "drug residues" category.

* NMED sampled the Rio Grande at the BDD and the finished water tank.

- The removal efficiency of the BDD treatments for selected organics in the drug residue category is very consistent with the efficiency calculated in the reference study in Section VI. This fact adds credibility of the results of the TREAT study and confidence in the BDD treatments.
- 8. Table 4 shows previous testing of the Rio Grande for drug residue constituents. When compared with the TREAT study sampling, we can conclude that the concentrations of these unregulated compounds vary greatly throughout the year.

Drug Residue	Jun-16	DL	Jan-16	DL	Sep-15	DL	May-15	DL
Acetaminophen	ND	4.8	ND	4.9	ND	5	ND	4.8
alpha-Estradiol	ND	1.9	ND	2	ND	2	ND	1.9
Androstenedione	ND	0.95	ND	0.97	ND	1	ND	0.95
Atrazine	ND	0.95	ND	0.97	ND	1	1.4	0.95
beta-Estradiol	ND	1.9	ND	1.9	ND	2	ND	1.9
Bisphenol A	ND	9.5	21	9.7	ND	10	ND	9.5
Caffeine	6.6	1.9	12	1.9	9.6	2	13	1.9
Carbamazepine	ND	0.95	1.5	1	1.7	1	1.1	0.95
Deet	5.1	4.8	9.1	4.9	10	5	ND	4.8
Diazepam	ND	0.95	ND	0.97	ND	1	ND	0.95
Dilantin	ND	1.9	ND	2	ND	2	ND	1.9
Diclofenac	ND	1.9	ND	1.9	3.1	2	ND	1.9
Diethylstilbestrol	ND	2	ND	2	ND	2	ND	2
Estriol	ND	1.9	ND	1.9	ND	2	ND	1.9
Estrone	ND	4.8	ND	4.9	ND	5	ND	4.8
Ethinyl Estradiol	ND	1.9	ND	1.9	ND	2	ND	1.9
Fluoxetine	ND	0.95	ND	0.97	ND	1	ND	0.95
Gemfibrozil	ND	0.95	ND	0.97	ND	1	1.5	0.95
Hydrocodone	ND	4.8	ND	4.9	ND	5	ND	4.8
Ibuprofen	ND	0.95	ND	0.97	ND	1	ND	0.95
Iopromide	ND	9.5	ND	9.7	ND	10	ND	9.5
Meprobamate	ND	0.95	ND	0.97	ND	1	1	0.95
Methadone	ND	4.8	ND	4.9	ND	5	ND	4.8
Naproxen	1.2	0.95	2.1	0.97	ND	1	1	0.95
Oxybenzone	ND	19	ND	19	ND	20	ND	19
Pentoxifylline	ND	4.8	ND	4.9	ND	5	ND	4.8
Progesterone	ND	1.9	ND	1.9	ND	2	ND	1.9
Salicylic Acid	ND	19	ND	19	ND	20	20	19
Sulfamethoxazole	2.3	0.95	5.2	1	8.6	1	7	0.95
Testosterone	ND	1.9	ND	2	ND	2	ND	1.9
Triclosan	ND	48	ND	49	ND	50	ND	48
Trimethoprim	ND	4.8	ND	4.9	ND	5	ND	4.8

Table 4. Drug residues monitoring of Rio Grande at BDD during 2015-2016 period.

IX. CONCLUSIONS AND RECOMMNEDATIONS

1. All three sampling events of the TREAT study confirmed that the design of the study was well selected, properly executed, and successful in examining the efficiency of treatments at BDD. With that, BDD achieved an improvement in comparison to the previous study, the "CFA", which was conducted at BDD from 2012 until 2013.

Recommendations: Any future TREAT study should maintain the same design which simulates treatment conditions, samples the same volume of treated water throughout the treatment train and composites the samples. However, a longer period of time (at least 5-7 consecutive days) and multiple or daily composite samples should be considered in order to achieve more statistically reliable results.

2. The TREAT study achieved great results on a very modest budget. It confirmed the efficiency of the BDD treatments with respect to removal of solids and with respect to all metals (including radionuclides) which have high affinity to solid particles. BDD was designed to do so and BDD staff was able to confirm the efficiency of the design in a practical manner. **Recommendation:** Since the past TREAT study runs were conducted at low sediment conditions of the Rio Grande, any future studies on efficiency of treatments should be conducted at higher sediment loads of the raw water.

3. The projected costs for the TREAT studies were underestimated. The costs associated with TREAT scope exceeded the budgeted amount by at least 25% in each sampling event. Because of underfunding, the study was run for a less than optimal length of time (four (4) hours) and quality control samples typical for such studies were not be collected as desired. **Recommendation:** Any future study should be approved with the appropriate budget and funding in order to achieve the highest quality results.

4. The TREAT study was designed on a very small scale, however because it is labor intensive, it placed a good deal of pressure on the BDD staff (Operations and Compliance Departments) with respect to planning and execution. BDD in its nucleus is a drinking water production facility and it is staffed for that single purpose.

<u>Recommendation</u>: Any future study should be broken into phases allowing staff sufficient time to provide the required oversight, or consideration should be given to the employment of a temporary staff, or BDD management should ensure the chosen contractor is capable of conducting the study with limited assistance.

5. The TREAT study achieved great results for a limited number of contaminants. There are contaminants that should be examined in greater detail and others that should be considered.

<u>Recommendation</u>: Before a study on this scale is conducted, the constituents to be included should be carefully selected given the known and anticipated contaminants of the source water.

X. QUESTIONS

For any questions or concerns about this report please contact the BDD Regulatory Compliance Officer, Daniela Bowman at 505-955-4504 or at email <u>dkbowman@santafenm.gov</u>

XI. APPENDIX: Data Tables for TREAT Study runs #1, #2, and #3

RG is the Sampling Station at the Rio Grande

SS1 is the Sampling Station 1

SS2 is the Sampling Station 2

SS3 is the Sampling Station 3

SS4 is the Sampling Station 4

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TREAT RUN # 1

Date of Sample				3/2	22/2016 - 3/23/20	016	*****	
	TREAT Samp	le Location	RG	SS1	SS2	SS3	SS4	1
S	ample Location I	Description	Rio Grande	Raw Water	After Conventional Treatment	After Membrane Filter	After GAC	Efficiency
	Contract	Laboratory	Hall	Hall	Hall	Hall	Hall	
Group	Analyte	Units					•	
	SSC Coarse	mg/L	< 1.00	1.45	< 1.00	< 1.00	< 1.00	
SSC	SSC Fine	mg/L	28.3	45.8	2.68	< 1.00	< 1.00	
	SSC Total	mg/L	28.3	47.3	2.68	< 1.00	< 1.00	> 96.5%
	тос	mg/L	2.5	2.5	1.9	1.8	1.6	36.0%
	Conductivity	µmhos/cm	230	220	240	240	240	
	TDS	mg/L	162	164	160	154	153	
Misc	Chloride	mg/L	4.5	4.5	19	19	19	
	Fluoride	mg/L	0.26	0.25	0.25	0.27	0.26	
	Sulfate	mg/L	22	22	23	23	23	
	Nitrate/Nitrite	mg/L	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
	Aluminum	mg/L	0.56	0.50	0.040	< 0.020	< 0.020	> 96.4%
	Antimony	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	nd
	Arsenic	mg/L	0.0016	0.0016	< 0.0010	< 0.0010	< 0.0010	> 37.5%
	Barium	mg/L	0.049	0.046	0.031	0.030	0.033	soluble
	Beryllium	mg/L	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.0020	nd
	Boron	mg/L	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040	nd
	Cadmium	mg/L	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.0020	nd
	Calcium	mg/L	25	25	27	27	26	hi soluble
	Chromium	mg/L	< 0.0060	< 0.0060	< 0.0060	< 0.0060	< 0.0060	nd
	Cobalt	mg/L	< 0.0060	< 0.0060	< 0.0060	< 0.0060	< 0.0060	nd
	Copper	mg/L	0.0029	0.0029	0.0012	0.0014	< 0.0010	> 65.5%
Total	Iron	mg/L	0.77	0.73	0.88	< 0.020	< 0.020	> 97.4%
Metals	Lead	mg/L	0.0026	0.0024	< 0.00050	< 0.00050	< 0.00050	> 80.8%
	Magnesium	mg/L	5.0	5.0	5.1	5.0	5.0	hi soluble
	Manganese	mg/L	0.11	0.093	0.039	0.035	< 0.0020	> 98.2%
	Mercury	mg/L	< 0.00020	< 0.00020	< 0.00020	< 0.00020	< 0.00020	nd
	Nickel	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	nd
	Potassium	mg/L	2.4	2.3	2.5	2.5	2.5	hi soluble
	Selenium	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	nd
	Silver	mg/L	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	nd
	Sodium	mg/L	12	12	13	13	13	hi soluble
	Thallium	mg/L_	< 0.00050	< 0.00050	< 0.00050	< 0.00050	< 0.00050	nd
	Uranium	mg/L	0.0019	0.0018	0.0012	0.0011	< 0.0005	> 73.7%
	Vanadium	mg/L	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	nd
L	Zinc Zinc	mg/L	0.012	0.023	< 0.010	< 0.010	< 0.010	> 56.5%

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	Date	of Sample		3/3	22/2016 - 3/23/20	016		Í	
	TREAT Samp	le Location	RG	SS1	SS2	SS3	SS4	1	
Si	ample Location [Rio Grande	Raw Water	After Conventional	After Membrane	After GAC	Ef	ficlency	
	Contract	i aboratory	Hall	Hall	Hall	Filler	<u>Цан</u>		
Group	Analyte	Units	1 (G1)		rian -	nali		-	
Metals Dissolved		mg/L		not analyzed					
Total	PCBs (total								
PCBs	congeners)	pg/L	< 20.1	< 20.4	< 20.2	< 20.1	< 20.2		
	Gross alpha	pCi/L	< 2.80	3.99	< 2.86	< 2.17	< 2.60	>	34.8%
	Gross beta	pCi/L	5.58	7.17	2.45	< 2.95	< 2.89	>	59.7%
	Ra-226	pCi/L	0.265	0.490	0.216	0.296	0.285		41.8%
	Ra-228	pCi/L	< 0.467	< 0.459	< 0.475	< 0.471	< 0.481		nd
	Am-241	pCi/L	< 0.040	< 0.0679	< 0.0722	< 0.0401	< 0.0376		nd
Pade	Pu-238	pCi/L	< 0.0797	< 0.0542	< 0.0179	< 0.0582	< 0.0162		nd
naus	Pu-239/240	pCi/L	< 0.086	< 0.0723	< 0.0521	< 0.0456	< 0.0472		nd
	U-234	pCi/L	1.06	0.967	0.620	0.617	0.331		68.8%
	U-235	pCi/L	0.120	0.0405	0.0529	< 0.0601	0.0585		51.3%
	U-238	pCi/L	0.702	0.629	0.326	0.373	0.215		69.4%
	Sr-90	pCi/L	< 0.483	< 0.372	< 0.310	< 0.471	< 0.477		nd
	Tritium	pCi/L	12.5	10.2	9.39	14.8	12.8		soluble
Gamma		pCi/L			NON-DETECT				
	Androsterone	ng/L	< 51.9	< 47.7	227	< 48.1	< 28.2	>	87.6%
	Mestranol	ng/L	118*	150*	97.8*	120*	101*		QC
	Acetaminophe								
	n	ng/L	< 15.3	45.2	< 15.6	< 15.2	< 15.6	>	65.5%
	Caffeine	ng/L	< 15.3	17.7	< 15.6	< 15.2	< 15.6	>	11.9%
Drug	Sulfamethoxaz								
Residues	ole	ng/L	3.92	3.76	1.05	1.04	< 0.623	>	84.1%
	Benzoylecgoni								
	ne	ng/L	< 0.305	0.407	< 0.565	< 0.303	< 0.311	 >	23.6%
	Benztropine	ng/L	0.601	< 0.507	< 0.519	< 0.506	< 0.519	>	13.6%
	Cocaine	ng/L	0.232	0.304	1.96	< 0.152	< 0.156	>	92.0%
	DEET	ng/L	18.3	1.89	2.04	1.35	1.14		93.8%

Notes:

*An instrumental interference was observed for Mestranol. Result is an estimated maximum concentraion only.

Data are not marked with laboratory qualifiers which may indicate a data quality

A "<" value is equivalent to a "non-detect" value; the number represents the detection limit

">" means greater than [the following number]

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TREAT RUN # 2

	Date	of Sample		g	5/9/2016 - 5/10/2	2016		
	TREAT Samp	le Location	RG	SS1	SS2	SS3	SS4	-
					After	After		
	Sample Location I	Description	Rio Grande	Raw Water	Conventional	Membrane	After GAC	Efficiency
					Treatment	Filter		
	Primary Contract	Laboratory	Hall	Hall	Hall	Hall	Hall	
Group	Analyte	units					****	
SSC	SSC Coarse	mg/L	< 1.00	3.33	< 1.00	< 1.00	< 1.00	
	SSC Fine	mg/L	59.0	27.90	2.21	2.32	< 1.00	
	SSC Total	mg/L	59.0	31.20	2.21	2.32	< 1.00	> 98.3%
	тос	mg/L	4.7	4.1	2.5	2.4	1.9	59.6%
	Conductivity	µmhos/cm	260	260	280	290	280	
	TDS	mg/L	206	196	194	194	192	and a Descent of the
Misc	Chloride	mg/L	4.1	4.1	24	24	23	
	Fluoride	mg/L	0.30	0.26	0.27	0.29	0.27	
	Sulfate	mg/L	34	34	34	34	35	
	Nitrate/Nitrite	mg/L	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
	Aluminum	mg/L	2.3	1.5	0.031	< 0.020	< 0.020	> 99.1%
	Antimony	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	nd
	Arsenic	mg/L	0.0019	0.0017	< 0.0010	< 0.0010	< 0.0010	> 47.4%
	Barium	mg/L	0.083	0.063	0.042	0.041	0.041	soluble
	Beryllium	mg/L	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.0020	nd
	Boron	mg/L	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040	nd
	Cadmium	mg/L	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.0020	nd
	Calcium	mg/L	32	30	30	30	30	hi soluble
	Chromium	mg/L	< 0.0060	< 0.0060	< 0.0060	< 0.0060	< 0.0060	nd
	Cobalt	mg/L	< 0.0060	< 0.0060	< 0.0060	< 0.0060	< 0.0060	nd
	Copper	mg/L	0.0063	0.0049	0.0019	0.0031	< 0.0010	> 84.1%
Total	Iron	mg/L	2.3	1.5	0.92	< 0.020	< 0.020	> 99.1%
Motals	Lead	mg/L	0.0036	0.0024	< 0.00050	< 0.00050	< 0.00050	> 86.1%
IVIC COIS	Magnesium	mg/L	6.0	5.6	5.5	5.4	5.6	hi soluble
	Manganese	mg/L	0.15	0.1	0.062	0.057	< 0.002	> 98.7%
	Mercury	mg/L	< 0.00020	< 0.00020	< 0.00020	< 0.00020	< 0.00020	nd
	Nickel	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	nd
	Potassium	mg/L	2.8	2.5	2.4	2.3	2.4	hi soluble
	Selenium	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	nd
	Silver	mg/L	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	nd
	Sodium	mg/L	13	13	14	14	15	hi soluble
	Thallium	mg/L	< 0.00050	< 0.00050	< 0.00050	< 0.00050	< 0.00050	nd
	Uranium	mg/L	0.0019	0.0018	0.00068	0.00052	< 0.00050	> 73.7%
	Vanadium	mg/L	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	nd
	Zinc	mg/L	0.027	0.015	< 0.010	< 0.010	< 0.010	> 63.0%

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	Date	of Sample	5/9/2016 - 5/10/2016						
	TREAT Samp	le Location	RG	SS1	SS2	SS3	SS4		
	Sample Location Description				After	After			
				Raw Water	Conventional	Membrane	After GAC	Efficiency	
					Treatment	Filter			
	Primary Contract	Hall	Hall	Hall	Hall	Hall			
Analyte	Analyte	units							
	Aluminum	mg/L	0.093	0.084	< 0.020	< 0.020	< 0.020		
	Antimony	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010		
	Arsenic	mg/L	0.0012	0.0013	< 0.0010	< 0.0010	< 0.0010		
	Barium	mg/L	0.043	0.042	0.040	0.039	0.038		
	Beryllium	mg/L	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.0020		
	Boron	mg/L	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040		
	Cadmium	mg/L	< 0.0020	< 0.0020	< 0.0020	< 0.0020	< 0.0020		
	Calcium	mg/L	28	28	28	28	28		
	Chromium	mg/L	< 0.0060	< 0.0060	< 0.0060	< 0.0060	< 0.0060		
	Cobalt	mg/L	< 0.0060	< 0.0060	< 0.0060	< 0.0060	< 0.0060		
	Copper	mg/L	0.0020	0.0019	0.0015	0.0029	0.0011		
Metals	Iron	mg/L	0.070	0.071	< 0.020	< 0.020	< 0.020	na	
Dissolve	Lead	mg/L	< 0.00050	< 0.00050	< 0.00050	< 0.00050	< 0.00050		
d	Magnesium	mg/L	5.2	5.2	5.4	5.3	5.4		
	Manganese	mg/L	0.0032	0.0036	0.059	0.056	< 0.0020	-	
	Mercury	mg/L	not analyzed						
	Nickel	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010		
	Potassium	mg/L	2.3	2.3	2.3	2.3	2.3]	
	Selenium	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010]	
	Silver	mg/L	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050		
	Sodium	mg/L	14	14	15	15	15		
	Thallium	mg/L	< 0.00050	< 0.00050	< 0.00050	< 0.00050	< 0.00050		
	Uranium	mg/L	0.00160	0.00160	0.00055	0.00053	< 0.00050		
	Vanadium	mg/L	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050]	
	Zinc	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010]	
Total	PCBs (total								
PCBs	congeners)	pg/L	< 20.4	< 20.2	< 20.9	< 20.7	< 21.0		

	Date	of Sample	5/9/2016 - 5/10/2016						
	TREAT Samp	le Location	RG	SS1	SS2	SS3	SS4		
					After	After			
	Sample Location I	Description	Rio Grande	Raw Water	Conventional	Membrane	After GAC	Eff	lciency
					Treatment	Filter			
	Primary Contract	Laboratory	Hall	Hall	Hall	Hall	Hall		
Analyte	Analyte	units				·			
	Gross alpha	pCi/L	5.86	3.23	< 2.79	< 2.80	< 2.95	>	49.7%
	Gross beta	pCi/L	6.94	5.86	< 2.08	< 3.30	2.65		61.8%
	Ra-226	pCi/L	0.274	0.401	0.427	< 0.249	< 0.234	>	14.6%
	Ra-228	pCi/L	0.731	0.570	0.382	< 0.326	< 0.467	>	36.1%
	Am-241	pCi/L	< 0.0816	< 0.0519	< 0.0675	< 0.0644	< 0.0847		nd
Pade	Pu-238	pCi/L	< 0.0843	< 0.127	< 0.0809	< 0.114	< 0.0578		nd
Ndus	Pu-239/240	pCi/L	< 0.1360	< 0.1170	< 0.0721	< 0.125	< 0.107		nd
	U-234	pCi/L	1.12	0.564	0.435	0.439	0.157	>	86.0%
	U-235	pCi/L	< 0.111	0.0709	< 0.124	< 0.127	< 0.0581	>	47.7%
	U-238	pCi/L	0.432	0.613	0.286	0.228	0.137	>	68.3%
	Sr-90	pCi/L	< 0.484	< 0.474	< 0.490	< 0.488	< 0.475		nd
	Tritium	pCi/L	13,1	17.3	16.6	15.7	16.6	so	luble
Gamma									
Spectros	К-40	pCi/L	41.3	< 29.6	< 57.4	< 25.6	< 42.6		
	Androstenedione	ng/L	< 2.07	< 2.10	< 2.10	2.38	< 2.10		nd
	Desogestrel 3	ng/L	< 194	< 265	< 147	108	137		nd
	Mestranol	ng/L	156*	213*	155*	143*	115*		QC
	Caffeine	ng/L	88.7	38.6	< 15.7	< 17.3	< 15.8	>	82.2%
Drug Residues	Sulfamethoxazole	ng/L	2.64	3.41	1.46	0.98	< 0.630	>	81.5%
	1,7-								
	Dimethylxanthine	ng/L	68.6	< 63.1	< 62.9	< 69.1	< 63.0	>	8.2%
	Amitriptyline	ng/L	0.320	< 0.316	< 0.315	< 0.345	< 0.315	>	1.6%
	Benzoylecgonine	ng/L	0.414	< 0.316	< 0.315	< 0.345	< 0.315	>	23.9%
	DEET	ng/L	19.0	4.83	3.01	5.09	4.19	>	77.9%
	Theophylline	ng/L	73.0	< 63.1	< 62.9	< 69.1	< 63.0	>	13.7%

Notes:

Data are not marked with laboratory qualifiers

A "<" value is equivalent to a "non-detect" value; the number represents the detection limit

">" means greater than [the following number]

TREAT RUN # 3

Date of Sample								
	TREAT Samp	le Location	RG	SS1	SS2	SS3	SS4	
Sample Location Description			Rio Grande	Raw Water	After Conventional Treatment	After Membrane Filter	After GAC	Efficiency
P	rimary Contract	Laboratory	ALS	ALS	ALS	ALS	ALS	
Group	Analyte	units						
	SSC Coarse	mg/L	33.8	5.0	2.9	< 1	< 1	
SSC	SSC Fine	mg/L	121.4	85.2	16.2	< 1	< 1	
	SSC Total	mg/L	155.2	87.2	19.10	< 1	< 1	> 99.4%
	тос	mg/L	3.3	3.4	2.4	2.4	2	39.4%
	Conductivity	µmhos/cm	320	322	332	333	330	
	TDS	mg/L	190	200	200	200	200	
Misc	Chloride	mg/L	4.3	4.5	15	15	15	
	Fluoride	mg/L	0.29	0.31	0.31	0.31	0.31	
	Sulfate	mg/L	53	53	52	53	53	
	Nitrate/Nitrite	mg/L	0.059	0.19	0.084	0.095	0.11	
	Aluminum	mg/L	2.7	1.3	0.037	< 0.014	0.014	99.5%
	Antimony	mg/L	0.00015	0.00015	< 0.00011	< 0.00011	< 0.00011	> 26.7%
	Arsenic	mg/L	0.0028	0.0025	0.00035	0.0003	< 0.0002	> 92.9%
	Barium	mg/L	0.12	0.11	0.076	0.075	0.051	soluble
	Beryllium	mg/L	0.00035	< 0.00027	< 0.00027	< 0.00027	< 0.00027	> 22.9%
	Boron	mg/L	0.069	0.050	0.038	0.034	0.031	soluble
	Cadmium	mg/L	< 0.000088	< 0.000088	< 0.000088	< 0.000088	< 0.000088	nd
	Calcium	mg/L	41	39	37	38	37	hi soluble
	Chromium	mg/L	0.0021	0.0011	< 0.00088	< 0.00088	< 0.00088	> 58.1%
	Cobalt	mg/L	0.0011	0.00068	0.00011	< 0.000083	< 0.000083	> 92.5%
	Copper	mg/L	0.0032	0.0044	0.0019	0.0015	< 0.0012	> 62.5%
Tatal	Iron	mg/L	2.0	0.96	0.37	0.024	0.0084	99.6%
Iotai	Lead	mg/L	0.0018	0.0012	< 0.00017	< 0.00017	< 0.00017	> 90.6%
Metals	Magnesium	mg/L	7.1	6.6	6.2	6.1	6.1	hi soluble
	Manganese	mg/L	0.096	0.079	0.023	0.023	0.00055	99.4%
	Mercury	mg/L	< 0.00006	< 0.00006	< 0.00006	< 0.00006	< 0.00006	nd
	Nickel	mg/L	< 0.004	0.0044	< 0.004	0.0081	0.006	nd
	Potassium	mg/L	2.9	2.5	2.3	2.3	2.6	hi soluble
	Selenium	mg/L	< 0.00066	< 0.00066	< 0.00066	< 0.00066	< 0.00066	nd
	Silver	mg/L	< 0.000041	< 0.000041	< 0.000041	< 0.000041	< 0.000041	nd
	Sodium	mg/L	16	16	17	17	16	hi soluble
	Thallium	mg/L	0.00002	< 0.000018	< 0.000018	< 0.000018	< 0.000018	nd
	Uranium	mg/L	0.0016	0.0015	0.0013	0.0013	0.0015	6.3%
	Vanadium	mg/L	0.0073	0.0059	< 0.00071	< 0.00071	< 0.00071	> 90.3%
	Zinc	mg/L	< 0.0098	0.018	< 0.0098	< 0.0098	< 0.0098	> 45.6%

Date of Sample			9/14/2016 - 9/15/2016					
TREAT Sample Location			RG	SS1	SS2	SS3	\$\$4]
					After	After		
Sar	nple Location D	escription	Rio Grande	Raw Water	Conventional	Membrane	After GAC	Efficiency
					Treatment	Filter		
Pri	Primary Contract Laboratory			ALS	ALS	ALS	ALS	Same and the second
	Aluminum	mg/L	0.057	0.028	< 0.014	0.024	0.016	na
	Antimony	mg/L	0.00023	0.00019	0.00014	0.00013	0.00017	
	Arsenic	mg/L	0.002	0.0022	0.00025	0.00026	0.00023	
	Barium	mg/L	0.086	0.085	0.077	0.075	0.052	
	Beryllium	mg/L	< 0.00027	< 0.00027	< 0.00027	< 0.00027	< 0.00027	
	Boron	mg/L	0.072	0.046	0.035	0.033	0.031	
	Cadmium	mg/L	< 0.000088	< 0.000088	< 0.000088	< 0.000088	< 0.000088	
	Calcium	mg/L	39	37	37	38	37	
	Chromium	mg/L	< 0.00088	< 0.00088	< 0.00088	< 0.00088	< 0.00088	
	Cobalt	mg/L	0.0019	0.0018	0.00017	0.00023	0.00011	
	Copper	mg/L	0.0021	0.0025	0.0019	0.0017	0.0014	
Motole	tron	mg/L	0.230	0.070	0.038	0.060	0.048	
Discolud	Lead	mg/L	< 0.00017	< 0.00017	< 0.00017	< 0.00017	< 0.00017	
Dissolved	Magnesium	mg/L	6.2	6.1	6.0	6.2	6.0	
	Manganese	mg/L	0.0056	0.0033	0.020	0.023	0.00079	
	Mercury	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002]
	Nickel	mg/L	< 0.004	< 0.004	< 0.004	< 0.004	0.0064	
	Potassium	mg/L	2.4	2.2	2.3	2.3	2.3	
[Selenium	mg/L	< 0.00066	< 0.00066	< 0.00066	< 0.00066	< 0.00066	
	Silver	mg/L	< 0.000041	< 0.000041	< 0.000041	< 0.000041	0.00005]
	Sodium	mg/L	16	16	16	17	17	
	Thallium	mg/L	< 0.000018	< 0.000018	< 0.000018	< 0.000018	< 0.000018	
	Uranium	mg/L	0.0014	0.0014	0.0013	0.0012	0.0015	
	Vanadium	mg/L	0.0038	0.0037	< 0.00071	< 0.00071	< 0.00071]
	Zinc	mg/L	0.037	< 0.0098	< 0.00980	< 0.0098	< 0.0098]
Total PCBs	PCBs (total congeners)	pg/L	327	297	not ar	nalyzed	179	45.3%
	Date of Sample 9/14/2016 - 9/15/2016				Efficiency			
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	TREAT Sampl	e Location	RG	SS1	SS2	SS3	SS4	- chiclency
Sa	mple Location D	Description	Rio Grande	Raw Water	After Conventional Treatment	After Membrane Filter	After GAC	
Pr	imary Contract	Laboratory	ALS	ALS	ALS	ALS	ALS	
	Gross alpha	pCi/L	3.00	2.17	1.35	< 0.86	< 0.82	> 72.7%
	Gross beta	pCi/L	6.34	4.29	2.75	2.85	3.05	51.9%
	Ra-226	pCi/L	< 0.180	< 0.151	0.146	< 0.126	< 0.134	nd
	Ra-228	pCi/L	< 0.66	< 0.92	< 0.65	< 0.82	< 0.78	nd
	Am-241	pCi/L	< 0.0356	< 0.0347	< 0.0331	< 0.0347	< 0.0345	nd
Bode	Pu-238	pCi/L	< 0.0196	< 0.0219	0.0153	< 0.0249	< 0.0164	nd
Raus	Pu-239/240	pCi/L	< 0.0219	0.0164	< 0.0269	0.0231	0.0124	43.4%
	U-234	pCi/L	0.998	0.823	0.802	0.828	0.931	6.7%
	U-235	pCi/L	0.0284	0.0221	0.0314	0.0227	0.042	neg
	U-238	pCi/L	0.608	0.517	0.5	0.454	0.578	4.9%
	Sr-90	pCi/L	< 0.171	< 0.158	< 0.148	< 0.159	< 0.142	nd
	Tritium	pCi/L	< 300	< 300	< 300	< 300	< 300	nd
Gamma								
Spectoros	Ac-228	pCi/L	17.5	< 14.3	< 18.5	< 32	20	
	Triclosan	ng/L	< 52	68			< 53	> 22.1%
	Caffeine	ng/L	< 2.1	26]		9.4	63.8%
Davia	Sulfamethoxa							
Diug	zole	ng/L	6.9	7.6	not ar	alyzed	< 1.1	> 85.5%
residues	DEET	ng/L	130	25			10	92.3%
	Diclofenac	ng/L	15	< 2.1			< 2.1	> 86.0%
	Oxybenzone	ng/L	100	24]		< 21	> 79.0%

Notes:

Data are not marked with laboratory qualifiers

A "<" value is equivalent to a "non-detect" value; the number represents the detection limit

">" means greater than [the following number]

TREAT RUN # 4

The TREAT study run #4 is eliminated from this study because the results suggest that TREAT samples were contaminated during the process of collection and handling of the samples and/or a major lab error occurred in metals analysis by the contract laboratory. The results of this run are not presented here.

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BDDB/LANL 2010 MOU

Contaminant Fate Analysis Study Mar 2012 – Feb 2013

I. Objective of Study

The 2010 MOU outlines that samples from the BDD intake, Sediment Removal Facility and the finished water will be collected and analyzed for the constituents in the Table below. In addition, the MOU stated that the collection of the samples will be in accordance with standard operating procedure developed by DOE and NMED.

Analytes	Method	Detection Limit	Field Prep Code
Gross alpha	EPA:900	3 pCi/L	F, UF
Gross beta	EPA:900	3 pCi/L	F, UF
Sr-90	EPA:905.0	0.5 pCi/L	F, UF
Am-241	HASL-300:AM-241	0.05 pCi/L	F, UF
Gross gamma	EPA:901.1	15 pCi/L	F, UF
Cs-137	EPA:901.1	5 pCi/L	F, UF
Co-60	EPA:901.1	5 pCi/L	F, UF
Na-22	EPA:901.1	10 pCi/L	F, UF
Np-237	EPA:901.1	40 pCi/L	F, UF
K-40	EPA:901.1	75 pCi/L	F, UF
Pu (isotopic)	HASL-300:ISOPU	0.05 pCi/L	F, UF
U (isotopic)	HASL-300:ISOU	0.05 pCi/L	F, UF
Ra-226, -228	903.1, 904	1 pCi/L	F, UF

The 2010 MOU was not very clear on the objective(s) of the study providing only high level vision. This report will assume that the objective of the study was to demonstrate the efficiency of the BDD treatments with respect to the contaminants listed in the table above.

<u>Recommendation</u>: It is recommended that the objectives or goals of any future study are clearly defined, as the sampling design, quality of the data, and the analysis of the results will be dependent on the goals.

II. Constituents of Concern (COCs).

The CFA is part of the 2010 MOU, and, therefore the constituents of concern (COCs) listed in the table above were selected as being LANL-legacy constituents, specifically, the COCs associated with Los Alamos/Pueblo Canyons watershed upstream from BDD. However, if the objective of the study is to examine the efficiency of the BDD treatments then the COCs in the table should be revised and not restricted to LANL-based constituents.

<u>Recommendation</u>: After the goals of the study are determined, the COCs should be selected in order to fulfill the goals. Then, the quality of the data will be determined, and, therefore the desired detection limits. It is recommended that when conducting a study associated with the BDD treatment efficiency, an expanded list of COCs be considered, and that the results are compared not only with the capabilities of the BDD treatments but with the MCLs for the selected COCs.

III. Sampling Design.

The 2010 MOU does not provide any special sampling instructions other than 1) samples are collected from the BDD intake, sediment return line, and finished water, and 2) the collected samples must be a monthly composites of flow weighted daily sampling.

Because samples were collected from the points listed above, there is no reference of "before" treatment sampling, but only "after" (which is the finished water tank). As an example, during the CFA study, the Rio Grande (RG) was sampled as opposed to the raw water being pumped through the intake structure. It is very likely that the sample was not representative of the intake water as typically the top 2-3 feet of the Rio Grande contains significantly less solids than the water being pulled from the bottom of the river bed where the BDD raw water screens are located. Thus the "before" treatment is neither the river intake, nor the difference between the river water and the sediment removal facility water. Therefore, the relationship between the river samples and the finished water may be skewed.

It is believed that the collection of monthly composites do not provide a good evaluation of the efficiency of the BDD treatments, as composition of samples represent anywhere between a 15 to 30 times dilution depending on how much volume of water is being treated. With so much dilution, the comparisons of "before" and "after" become "smeared" or averaged. Problems may not be identified since they are "averaged" by the large dilution. It is BDD's staff opinion that long term compositing is appropriate only after a study had well documented variations in the treatment system.

<u>Recommendation</u>: The sampling points should be modified in order to collect true "before" and "after" samples. The "before" collection point should be either the raw water intake line, or water brought to the pre-sedimentation basins. In addition, it is recommended that the sampling of the finished water come from the same volume of water. Therefore, the sampling would occur after the requisite time necessary for the raw water to pass through the treatment system (as determined by BDD's Operations) so that proper "after" samples be collected. In general, for a "before and after" study of treatment systems, scientific studies in the literature use 24-hr time-composited flow weighted samples. As part of the QA/QC of the study, water quality parameters might be collected and documented as well such as

turbidity, SSC, pH, TOC, temperature, and other pertinent parameters in order to demonstrate and ensure normal regime of operation during the sampling day/term.

IV. Samples Handling and Laboratory Analyses.

When the CFA was conducted, daily samples were collected and stored at room temperature until the last sample for the month was collected. The samples were neither refrigerated, nor preserved. After the last sample for the month was collected, samples were composited (mixed together) and some volume of that mixture was filtered through a 41 micron filter. Then, the samples were bottled, preserved, and shipped to an outside analytical laboratory.

This type of handling of the samples does not comply with approved EPA methods. The samples should be preserved with nitric acid within five days of their collection. Since proper laboratory procedures were not followed, the results from the analyses could be underestimating the concentrations of contaminants.

<u>Recommendation</u>: For future studies, it is recommended that proper handling and preservation methods as described in the analytical procedure(s) be researched prior to initiating a study. If any compositing of samples is required then refrigeration and lower detection limits should be implemented as well.

V. Results of the CFA.

The table below summarizes the results of the 2012/2013 CFA. Note that if a constituent was not detected in either of the samples, then it was not included in this table. One exception is Plutonium-238 that was measured at 0.272 pCi/L in the Rio Grande. This was the only detection of the contaminant and it was detected in the monthly river sample on 7/31/2012.

Sample source	Analyte	No. Detects	Range (min- max) pCi/L	MCL or NMQCC Standard pCi/L
Rio Grande at BDD Intake	Bismuth-214	1 of 12	ND - 14,3	NA
BDD Sediment Removal Facility	Bismuth-214	2 of 12	ND - 9.96	NA
BDD Finished Water Facility	Bismuth-214	3 of 12	ND - 24.30	NA
Rio Grande at BDD Intake	Gross alpha	9 of 12	ND - 44.70	15 pCi/L
BDD Sediment Removal Facility	Gross alpha	8 of 12	ND - 38.80	NA
BDD Finished Water Facility	Gross alpha	5 of 12	ND - 7.42	15 pCi/L
Rio Grande at BDD Intake	Gross beta	12 of 12	ND - 76.8	NA
BDD Sediment Removal Facility	Gross beta	12 of 12	3.35 - 114.00	NA
BDD Finished Water Facility	Gross beta	8 of 12	ND - 603	Dose 4 mrem; Screening level 50 pCi/L (w/o K-40)

Sample source	Analyte	No. Detects	Range (min- max) pCi/L	MCL or NMQCC Standard pCi/L
Rio Grande at BDD Intake	Potassium-40	4 of 12	ND - 104	None
BDD Sediment Removal Facility	Potassium-40	3 of 12	ND - 74.9	None
BDD Finished Water Facility	Potassium-40	1 of 12	ND - 45.9	None
Rio Grande at BDD Intake	Lead-212	1 of 12	ND - 11.3	None
BDD Sediment Removal Facility	Lead-212	2 of 12	ND - 10.9	None
BDD Finished Water Facility	Lead-212	1 of 12	ND - 10.3	None
	1	2 - (12	ND 017	
RIO Grande at BDD Intake	Lead-214	3 01 12	ND - 21.7	None
BDD Sediment Removal Facility	Lead-214	0 of 12	ND	None
BDD FINISNED Water Facility	Lead-214	0 01 12	ND	None
Rio Grande at BDD Intake	Radium-226	6 of 12	ND - 1.39	None
BDD Sediment Removal Facility	Radium-226	10 of 12	ND - 1.09	None
BDD Finished Water Facility	Radium-226	5 of 12	ND - 1.23	None
Rio Grande at BDD Intake	Radium-226 and Radium- 228	7 of 12	ND - 5.91	30 pCi/L
BDD Sediment Removal Facility	and Radium-226 228	9 of 12	ND - 2.18	None
BDD Finished Water Facility	Radium-226 and Radium- 228	6 of 12	ND - 1.23	5 pCi/L
Rio Grande at BDD Intake	Radium-228	4 of 12	ND - 4.52	None
BDD Sediment Removal Facility	Radium-228	6 of 12	ND - 1.51	None
BDD Finished Water Facility	Radium-228	4 of 12	ND - 0.88	None
Rio Grande at BDD Intake	Thallium-208	1 of 12	ND - 4.31	None
BDD Sediment Removal Facility	Thallium-208	1 of 12	ND - 6.95	None
BDD Finished Water Facility	Thallium-208	3 of 12	ND - 5.8	None
			0.010 0.07	•••
RIO Grande at BDD intake	Uranium-234	12 01 12	0.612 - 2.07	None
BDD Sediment Removal Facility	Uranium-234	12 of 12	0.515 - 2.67	None
Finished Water Facility	Uranium-234	12 of 12	0.079 - 1.78	INONE
Rio Grande at BDD Intake	Uranium-235	6 of 12	ND - 0.10	None
BDD Sediment Removal Facility	Uranium-235	7 of 12	ND - 0.10	None
BDD Finished Water Facility	Uranium-235	3 of 12	ND - 0.08	None

Sample source	Analyte	No. Detects	Range (min- max) pCi/L	MCL or NMQCC Standard pCi/L
Rio Grande at BDD Intake	Uranium-238	12 of 12	0.37 - 1.84	None
BDD Sediment Removal Facility	Uranium-238	12 of 12	0.31 - 2.38	None
BDD Finished Water Facility	Uranium-238	12 of 12	0.05 - 1.06	None

As pointed out earlier in this report, the study does not have true "before treatment" samples. However, an effort was made to analyze the efficiency of the BDD treatments in terms of calculating the percent removal (efficiency=after concentration/before concentration) for the gross alpha, gross beta, radium, and uranium radionuclides. See table below.

Analyte	Date	Intake (UF)	Finished (UF)	Efficiency
	03/31/2012	19.5	2.26	88.4%
	04/30/2012	2.44	<2.36	na
	05/31/2012	2.88	<2.86	na
	06/30/2012	<2.44	<2.50	na
	07/31/2012	14.9	5.05	66.1%
Gross Alpha	08/31/2012	44.7	<3.37	>92.4%
	09/30/2012	8.78	3.98	54.7%
	10/31/2012	<4.33	<2.98	na
	11/30/2012	3.21	7.42	-131%
	12/31/2012	<2.78	<3.00	na
	01/31/2013	6.85	4.56	33.4%
	02/28/2013	3.67	2.18	40.6%
	03/31/2012	30.5	<3.71	>88%
	04/30/2012	7.05	<2.85	>60%
	05/31/2012	<2.98	<3.00	na
	06/30/2012	<2.98	3.83	NEG
	07/31/2012	32.6	21.3	34.7%
Gross beta	08/31/2012	76.8	8.23	89.3%
	09/30/2012	8.73	19.2	-120%
	10/31/2012	17.0	603.0	-3447%
	11/30/2012	23.5	50.5	-115%
	12/31/2012	3.75	<2.97	>21%
	01/31/2013	28.1	6.5	76.9%
	02/28/2013	5.74	14.1	-146%
	03/31/2012	ND	ND	na
	04/30/2012	0.587	1.23	-110%
Radium 226	05/31/2012	ND	ND	na
	06/30/2012	ND	ND	na
-	07/31/2012	1.08	1.09	-0.9%

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Analyte	Date	Intake (UF)	Finished (UF)	Efficiency
	08/31/2012	1.39	ND<0.344	>75%
	09/30/2012	0.776	ND<0.636	na
	10/31/2012	0.527	0.636	-20.7%
Radium 226	11/30/2012	ND	ND	na
	12/31/2012	ND	ND	na
	01/31/2013	ND	ND	na
	02/28/2013	0.238	ND	na
	03/31/2012	ND<0.362	0.436	NEG
	04/30/2012	ND	ND	na
	05/31/2012	0.94	0.878	6.6%
	06/30/2012	ND	ND	na
	07/31/2012	ND	ND	na
Radium 228	08/31/2012	4.52	<0.618	>86%
	09/30/2012	ND	ND	na
	10/31/2012	ND	ND	na
	11/30/2012	ND<0.455	0.696	NEG
	12/31/2012	ND	ND	na
	01/31/2013	ND	ND	na
	02/28/2013	0.829	ND<0.769	na
	03/31/2012	0.911	0.35	61.6%
	04/30/2012	0.774	0.0797	89.7%
	05/31/2012	0.863	0.258	70.1%
	06/30/2012	0.612	0.138	77.5%
	07/31/2012	1.65	ND<0.27	>84%
Uranium 234	08/31/2012	2.07	0.0838	96.0%
oramuni 234	09/30/2012	1.35	0.434	67.9%
	10/31/2012	1.31	1.09	16.8%
	11/30/2012	1.4	1.4	0.0%
	12/31/2012	1.07	0.848	20.7%
	01/31/2013	1.71	1.78	-4.1%
	02/28/2013	1.66	1.34	19.3%
	03/31/2012	0.513	0.201	60.8%
	04/30/2012	0.495	0.0625	87.4%
	05/31/2012	0.416	0.182	56.3%
	06/30/2012	0.365	0.0827	77.3%
Uranium 238	07/31/2012	1.45	ND<0.134	>91%
	08/31/2012	1.84	0.0461	97.5%
	09/30/2012	0.944	0.278	70.6%
	10/31/2012	0.902	0.554	38.6%
	11/30/2012	0.91	0.996	-9.5%
	12/31/2012	0.713	0.562	21.2%

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Analyte	Date	Intake (UF)	Finished (UF)	Efficiency
	01/31/2013	1.12	1.06	5.4%
	02/28/2013	1.1	0.812	26.2%
	03/31/2012	ND	ND	na
	04/30/2012	ND	ND	na
	05/31/2012	0.03	ND<0.0253	na
	06/30/2012	ND	ND	na
	07/31/2012	0.0589	ND<0.114	na
Uranium 235	08/31/2012	0.102	ND<0.0264	>74%
	09/30/2012	ND	ND	na
	10/31/2012	0.0763	0.06	21.4%
	11/30/2012	ND	ND	na
	12/31/2012	ND	ND	na
	01/31/2013	0.0461	0.0836	-81.3%
	02/28/2013	0.0595	ND<0.041	na

VI. Analysis of the Data.

- 1) As a general rule, radionuclides attach to the particulates in the water. Therefore, it is expected that the finished water samples that were collected would have lower concentrations in comparison to the unfiltered raw water samples. This fact was observed for most of the results for gross alpha (80% of the time). However, the results for gross beta, radium, and uranium did not follow this trend. This anomaly in the data demonstrates a problem with the results, as the river samples have more solids than the finished water, and it is impossible for both samples to have similar results, or for the finished water to have greater values. This observation is likely proof of the shortcomings of the sampling design of the study.
- 2) The removal efficiency for the gross alpha, beta, radium, and uranium isotopes was attempted to be calculated. For the sampling events when gross alpha was detected, the removal efficiency of the treatments varied from 33% to more than 97%, with the exception of one event (11/2012) when the gross alpha in the finished water was 7.42 pCi/L but the river results was 3.21 pCi/L (an anomaly). The BDD treatments are conventional and advanced and highly effective in treating gross alpha. The calculated efficiency variability is unusual and not characteristic of the applied treatments.

The calculated efficiency for gross beta was 77% and 89% for two sampling events; the rest of the sampling events had too many anomalies and a valid efficiency could not be calculated. The Radium-226 removal efficiency varied from 85% to 95% for two sampling events only; the rest of the data was anomalous or ND.

The Radium-228 removal efficiency varied from 7% to 95% with a lot of anomalous data. Uranium removal efficiency varied from 17% to 96% with half of the data being anomalous. The results of the data strongly indicate that the design of the CFA study was not appropriate for evaluating the removal efficiency of the treatments at BDD.

VII. Recommendations.

It is the recommended that the study be repeated with the following modifications. For the before-andafter study a completely different approach needs to be adopted and a carefully designed sampling plan needs to be executed. Scientific literature should be researched for well accepted practices and designs of before-and-after studies. The quality of the sampling design is critical, as the data produced will be used to make decisions about the treatment processes for years to come.



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Efficiency of conventional drinking-water-treatment processes in removal of pharmaceuticals and other organic compounds

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Abstract

Samples of water and sediment from a conventional drinking-water-treatment (DWT) plant were analyzed for 113 organic compounds (OCs) that included pharmaceuticals, detergent degradates, flame retardants and plasticizers, polycyclic aromatic hydrocarbons (PAHs), fragrances and flavorants, pesticides and an insect repellent, and plant and animal steroids. 45 of these compounds were detected in samples of source water and 34 were detected in samples of settled sludge and (or) filter-backwash sediments. The average percent removal of these compounds was calculated from their average concentration in time-composited water samples collected after clarification, disinfection (chlorination), and granular-activated-carbon (GAC) filtration. In general, GAC filtration accounted for 53% of the removal of these compounds from the aqueous phase; disinfection accounted for 32%, and clarification accounted for 15%. The effectiveness of these treatments varied widely within and among classes of compounds; some hydrophobic compounds were strongly oxidized by free chlorine, and some hydrophilic compounds were partly removed through adsorption processes. The detection of 21 of the compounds in 1 or more samples of finished water, and of 3 to 13 compounds in every finished-water sample, indicates substantial but incomplete degradation or removal of OCs through the conventional DWT process used at this plant.

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Keywords: Organic chemicals; Drinking water; Pharmaceuticals

1. Introduction

More than 100,000 synthetic chemicals are used in a variety of domestic, industrial, and agricultural applications (Jørgensen, 2004). Numerous studies have documented that many of these compounds, including pharmaceuticals, fragrances and flavorants, flame retardants and plasticizers, detergent metabolites, components of personal care products, and products of petroleum use and combustion are incompletely degraded or removed during wastewater treatment and are persistent in the aquatic environment. Reviews of the occurrence and fate of organic compounds (OCs) in wastewaters and the aquatic environment are available (Metcalfe et al., 2004; Focazio et al., 2004; Daughton,

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2001; Halling-Sørensen et al., 1998; Daughton and Ternes, 1999). Fewer studies have documented the occurrence of these OCs in drinking-water supplies. Exceptions include documentation of low-level concentrations of OCs in plant-scale studies of drinkingwater supplies (Loraine and Pettigrove, 2006; Petrovic et al., 2003; Adams et al., 2002; Ternes et al., 2002; Reddersen et al., 2002; Heberer and Stan, 1997) and evaluation of their fate in laboratory-scale simulations of drinking-water-treatment (DWT) processes (Westerhoff et al., 2005; Huber et al., 2005; Pinkston and Sedlak, 2004; Zwiener and Frimmel, 2000).

In 2001, the potential for 106 OCs to survive a conventional DWT process and persist in finished. potable water was investigated (Stackelberg et al., 2004). The results provided the first documentation that a wide variety of OCs, most of which are currently unregulated in drinking-water supplies, can survive conventional DWT, but limitations in the study design precluded quantitative comparison of the degradation or removal of OCs by individual water treatments. Subsequent sampling at the same DWT plant in 2003 by the U.S. Geological Survey in cooperation with the New Jersey Department of Environmental Protection addressed these limitations by including (1) collection of multiple time-composited water samples at each treatment step to account for retention time through the DWT plant and diurnal variations in source-water quality, and (2) collection of solids samples for evaluation of the effectiveness of adsorptive processes in removing OCs. This paper uses data from the 2003 sampling to evaluate the average percent removal (concentration decreases) and fate of OCs that were detected in the DWT plant's source waters.

2. Description of DWT plant and sample collection

The DWT plant is in a heavily populated, highly urbanized drainage basin in which more than 50 STPs discharge effluent to the two streams (or their tributaries) that provide source water for the DWT plant. The DWT plant treats and provides an average of 235 million L/day to about 850,000 people. Supernatant water that is decanted from settled sludge and filter backwash sediments is recycled to the head of the plant (Fig. 1). This recycled water represents about 9% of water entering the treatment process. Three modifications to the treatment process were made after the 2001 study but before the 2003 sampling: (1) discontinuation of powder-activated carbon, (2) addition of microsand to enhance the clarification process, and (3) reversal of the order of clarification and primary disinfection. An additional difference was that the GAC in the filters in 2001 was 3 years old and nearly exhausted, whereas the GAC in the filters in 2003 was only 2 months old. Except for these modifications and the condition of the GAC filters, the treatment process at the time of the present study was as described in Stackelberg et al. (2004).

Sample collection entailed collection of 12 water samples at each of six sampling points (72 samples) over a 3-week period during July and August, 2003 (Fig. 1). The six sampling points represent source water (site 1), source and recycled water (site 2), settled water (site 3), disinfected water (site 4), filtered water (site 5), and finished water (site 6) (Fig. 1). To account for retention times in the DWT plant and diurnal variability in sourcewater quality, water samples were collected as constant flow, 24-h composites of 4-L by use of a metering pump. The composite samples were split into prebaked, 1-L amber-glass bottles that were chilled on ice and sent overnight to participating laboratories. The samples of disinfected, filtered, and finished effluents were preserved with 0.1 g ascorbic acid in the field to prevent further reaction with free chlorine (Westerhoff et al., 2005; Winslow et al., 2001). All water samples were filtered at participating laboratories with 0.7-µmnominal-pore-size glass-fiber filters prior to extraction and analysis, unlike the samples collected in the earlier



Fig. 1. Schematic diagram of primary-treatment processes and samplesite locations.

Table 1A

Compounds detected in source water or solids samples

Compound and method	CAS number	Use/category	RL water (μg/ L)	RL solids (µg/ kg)	DF in source water (%) (N=12)	Max in source water (µg/L)	DF in finished water (%) (N=12)	Max in finished water (µg/L)	Detected in solids samples? (Y/N)
Pharmaceuticals									
Acetaminophen *	103-90-2	Antipyretic	0.036	0.76	75	0.12	17	0	N
Caffeine	58-08-2	Stimulant	0.016	1.33	42	0.1	0	ND	N
Caffeine ^b	58-08-2		0.5	1.33	100	0.19	25	0.06	N
Carbamazepine ^a	298-46-4	Anticonvulsant	0.011	1.65	92	0.6	100	0.14	Y
Codeine ^a	76-57-3	Analgesic	0.015	1.32	8	0.01	8	0.03	N
Cotinine ^a	486-56-6	Nicotine degradate	0.014	1.3	92	0.01	75	0.02	N
Cotinine ^b	486-56-6		1.0	1.3	0	ND	0	ND	N
Dehydronifedipine ^a	067035-22-7	Nifedipine degradate	0.015	1.69	25	0	17	0	N
Diphenhydramine ^a	58-73-1	Antihistamine	0.015	1.35	0	ND	8	0	Y
Erythromycin ^c	114-07-8	Antibiotic	0.01	1.66	17	0.04	0	ND	N
Erythromycin ^d	114-07-8		0.10	1.66	0	ND	0	ND	N
Erythromycin-H ₂ O ^c		Erythromycin degradate	0.01	NA	58	0.01	0	ND	-
Fluoxetine*	54910-89-3	Antidepressant	0.014	2.17	0	ND	0	ND	Y
Lincomycin ^c	154-21-2	Antibiotic	0.01	NA	17	0.01	0	ND	
Lincomycin ^d	154-21-2		0.05	NA	8	0.06	0	ND	
Sulfadimethoxine ^c	122-11-2	Antibiotic	0.01	NA	8	0.01	0	ND	
Sulfadimethoxine ^d	122-11-2		0.05	NA	0	ND	0	ND	
Sulfamethazine ^e	57-68-1	Antibiotic	0.01	NA	17	0.04	0	ND	
Sulfamethazine ^d	57-68-1		0.05	NA	0	ND	0	ND	
Sulfamethoxazole ^c	723-46-6	Antibiotic	0.01	1.58	83	0.06	0	ND	N
Sulfamethoxazole ^d	723-46-6		0.05	1.58	D	ND	0	ND	N
Sulfathiazole ^c	72-14-0	Antibiotic	0.01	NA	8	0.08	8	0.01	
Sulfathiazole ^d	72-14-0		0.05	NA	0	ND	0	ND	
Detergent degradates									
4-Nonylphenol (NP) ^b	251-545-23	Detergent degradate	5	500	25	1.4	8	1.1	Y
Diethoxynonylphenol	-	Detergent	5	1000	17	2.6	0	ND	Y
(NP ₂ EO) ^b		degradate							
Diethoxyoctylphenol (OP ₂ EO) ^b	1/10mm	Detergent degradate	1	50	25	0.26	8	0.12	N
Ethoxyoctylphenol (OP ₁ EO) ^b		Detergent degradate	1	250	8	0.95	0	ND	Y
Flame retardants and plasticizers									
Tributyl phosphate (TBP) ^b	126-73-8	Flame retardant	0.5	50	42	0.14	8	0.18	Y
Triphenyl phosphate	115-86-6	Plasticizer	0.5	50	75	0.08	0	ND	Y
Tris(2-butoxyethyl)	78-51-3	Flame	0.5	100	100	0.57	0	ND	Y
phosphate		retardant	010				-		•
(IBEP)"	115.06.0	D1	0.5	100	100	0.10	0	0.05	N
phosphate	115-96-8	Plasticizer	0,5	100	100	0.12	8	0.05	Ν
(TCEP) ^b									
Tris	13674-87-8	Flame	0.5	100	100	0.11	17	0.07	Y
(dichloroisopropyl) phosphate (TDIP) ^b		retardant							
Bisphenol A ^P	80-05-7	Plasticizer	1	100	67	0.36	17	0.22	Y

(continued on next page)

Table 1A (continued)

Compound and method	CAS number	Use/category	RL water (μg/	RL solids (μg/	DF in source water (%)	Max in source water	DF in finished water (%)	Max in finished water	Detected in solids samples?
VE 2001			L)	kg)	(N=12)	(µg/L)	(N=12)	(µg/L)	(Y/N)
Polycyclic aromatic hydrocarbons (PAH)								
1-Methylnaphthalene ^b	90-12-0	PAH	0.5	50	0	ND	0	ND	Y
2,6-Dimethylnaphthalene ^b	581-42-0	PAH	0.5	50	0	ND	0	ND	Y
2-Methylnaphthalene ^b	91-57-6	PAH	0.5	50	0	ND	0	ND	Y
Anthracene ^b	120-12-7	PAH	0.5	50	17	0.06	0	ND	Y
Benzo[a]pyrene ^b	50-32-8	PAH	0.5	50	0	ND	0	ND	Y
Fluoranthene ^b	206-44-0	PAH	0.5	50	83	0.068	0	ND	Y
Naphthalene ^b	91-20-3	PAH	0.5	50	0	ND	0	ND	Y
Phenanthrene ^b	85-01-8	PAH	0.5	50	83	0.034	0	ND	Y
Pyrene ^b	129-00-0	PAH	0.5	50	83	0.059	0	ND	Y
Fragrances and flavorants									
3-Methyl-1H-indole	83-34-1	Fragrance	0.5	50	0	ND	0	ND	Y
(skatol) ^b		0							
Acetyl hexamethyl tetrahydro naphthalene (AHTN) ^b	21145-77-7	Fragrance	0.5	50	100	0.2	58	0.068	Y
Campbor ^b	76-22-2	Flavorant	0.5	50	33	0.014	25	0.017	N
Hexahydrohexamethyl cyclopentabenzopyran (HHCB) ^b	1222-05-5	Fragrance	0.5	50	92	0.085	0	ND	Y
Plant and animal steroids									
b-Sitosterol ^b	83-46-5	Plant sterol	2	500	17	0,93	0	ND	Y
b-Stigmastanol ^b	19466-47-8	Plant sterol	2	500	17	3.0	0	ND	Y
Cholesterol ^b	57-88-5	Fecal indicator/plant sterol	2	250	33	1.7	0	ND	Y
Pesticides, repellents, and adjuvant	\$								
Carbaryl ^b	63-25-2	Insecticide	1	NA	50	0.12	0	ND	
Carbazole ^b	86-74-8	Insecticide	0.5	50	42	0.072	0	ND	Y
N,N-Diethyltoluamide (DEET) ^b	134-62-3	Repellent	0.5	100	92	0.2	100	0.097	Y
Diazinon ⁶	333-41-5	Insecticide	0.5	50	50	0.14	0	ND	N
D-Limonene ^b	5989-27-5	Fungicide	0.5	50	8	0.0018	0	ND	N
Indole ^b	120-72-9	Adiuvant	0.5	50	0	ND	0	ND	Y
Metolachlor ^b	51218-45-2	Herbicide	0.5	50	58	0.11	0	ND	N
Miscellaneous									
1,4-Dichlorobenzene ^b	106-46-7	Deodorizer	0.5	50	17	0.048	0	ND	N
Anthraquinone ^b	84-65-1	Intermediate	0.5	50	58	0.16	0	ND	Y
Benzophenone ^b	119-61-9	Fixative	0.5	50	75	0.087	0	ND	N
Isophorone ^b	78-59-1	Solvent	0.5	50	0	ND	0	ND	Y
4-Cresol ⁶	106-44-5	Preservative	1	250	42	0.033	0	ND	Y
Tetrachloroethene ^b	127-18-4	Solvent	0.5	50	83	0.072	8	0.03	Y
Triclosan ^b	3380-34-5	Antimicrobial	1	50	0	ND	0	ND	Y
Triethyl citrate ^b	77-93-0	Cosmetics	0.5	NA	83	0.12	17	0.082	

RL, reporting level; DF, detection frequency; Max, maximum concentration; ND, not detected; NA, not analyzed; -, no data; Y, yes; N, no.
^a HPLC/MS-ESI(+).
^b GC/MS.
^c HPLC/MS-MS-ESI(+).
^d LC/MS-ESI(+).

Table 1B

Compounds not detected in source water or solids samples

Compound	CAS number	Use	RL water (µg/L)	
Pharmaceuticals				
1,7-Dimethylxanthine ^a	611-59-6	Caffeine degradate	0.144	2.03
Albuterol ^a	18559-94-9	Antiasthmatic	0.023	1.09
Amoxicillin ^b	61336-70-7	Antibiotic	0.20	NA
Ampicillin ^b	69-53-4	Antibiotic	0.10	NA
Anhydrochlorotetracycline ^b	-	Chlorotetracycline degradate	0.10	NA
Anhydrotetracycline ^b	4496-85-9	Tetracycline	0.20	NA
o c h	(0.500 AD /	degradate		
Cetotaxime	63527-52-6	Antibiotic	0.10	NA
Chlorotetracycline	57-62-5	Antibiotic	0.10	NA
Cimetiaine ⁻	51481-01-9	Antacid	0.012	0.88
Ciprofioxacin ⁻	85/21-33-1	Antibiotic	0.0005	NA
Clipronoxacin "	85/21-33-1	A Lotte for after	0.05	NA
Clinatioxacin	105956-97-6	Antibiotic	0.05	NA
Cloxactilm"	61-72-3	Antibiotic	0.10	NA
Demeclocycline	127-33-3	Antibiotic	0.10	NA
Diltiazem	42399-41-7	Antihypertensive	0.016	1.48
Doxycycline	564-25-0	Antibiotic	0.10	NA
Flumequine	42835-25-6	Antibiotic	0.05	NA
Gemtibrozil	25812-30-0	Antihyperlipidemic	0.013	5.46
Ibuproten"	15687-27-1	Antuntlammatory	0.042	NA
Lomefloxacin	98079-51-7	Antibiotic	0.05	NA
Miconazole "	22916-47-8	Antifungal	NA	0.97
Minocycline	10118-90-8	Antibiotic	0.018	NA
Norfloxacin	70458-96-7	Antibiotic	0.005	NA
Norfloxacin	70458-96-7		0.05	NA
Ofloxacin ^e	83380-47-6	Antibiotic	0.01	NA
Ofloxacin	83380-47-6		0.05	NA
Ormetoprim ¹	6981-18-6	Antibiotic	0.05	NA
Oxacillin	66-79-5	Antibiotic	0.10	NA
Oxolinic acid	14698-29-4	Antibiotic	0.05	NA
Oxytetracycline	6153-64-6	Antibiotic	0.10	NA
Penicillin G ^b	61-33-6	Antibiotic	0.10	NA
Penicillin V ^b	87-08-1	Antibiotic	0,10	NA
Ranitidine*	66357-35-5	Antacid	0,013	NA
Roxithromycin	80214-83-1	Antibiotic	0.10	NA
Sarafloxacin	98105-99-8	Antibiotic	0.005	NA
Sarafloxacin [®]	98105-99-8		0.05	NA
Sulfachloropyridazine	80-32-0	Antibiotic	0.005	NA
Sulfachloropyridazine	80-32-0		0.05	NA
Sulfadiazine	68-35-9	Antibiotic	0.05	NA
Sulfadiazine ¹⁰	68-35-9		0.05	NA
Sulfamerazine ^b	127-79-7	Antibiotic	0.05	NA
Tetracycline °	60-54-8	Antibiotic	0.10	NA
Thiabendazole ^a	148-79-8	Anthelmintic	0.011	1.04
Trimethoprim	738-70-5	Antibiotic	0.05	1.47
Trimethoprim ^b	738-70-5		0.05	1.47
Tylosin ^c	1401-69-0	Antibiotic	0.05	NA
Tylosin ^b	1401-69-0		0.10	NA
Virginiamycin ^b	21411-53-0	Antibiotic	0.10	NA
Warfarin ^a	81-81-2	Anticoagulant	0.012	1.26
Detergent degradates		.		
4-Cumylphenol	599-64-4	Detergent degradate	1	50
4-Octylphenol	sat	Detergent degradate	1	50
4-tert-Octylphenol"	Anna 1910 - Maria M	Detergent degradate	1	50

(continued on next page)

Compound	CAS number	Use	RL water (µg/L)	RL solids (µg/kg)	
Fragrances and flavorants					
Isoborneol ^d	124-76-5	Fragrance	0.5	50	
Isoquinoline ^d	119-65-3	Flavorant/fragrance	0.5	100	
Menthol ^d	89-78-1	Flavorant	0.5	50	
Pesticides, repellents, and adjuvants					
Bromacil ^d	314-40-9	Herbicide	0.5	100	
Chlorpyrifos ^d	2921-88-2	Insecticide	0.5	50	
Dichlorvos ^d	62-73-7	Insecticide	1	NA	
Metalaxyl ^d	57837-19-1	Herbicide	0.5	50	
Prometon ^d	1610-18-0	Herbicide	0,5	50	
Miscellaneous					
3-tert-Butyl-4-hydroxyanisole ^d	121-00-6	Antioxidant	5	NA	
5-Methyl-1H-benzotriazole ^d	136-85-6	Anticorrosive	2	NA	
Isopropylbenzene (cumene) ^d	98-82-8	Intermediate	0.5	50	
Methyl salicylate ^d	119-36-8	Liniment	0.5	100	
Pentachlorophenol ^d	87-86-5	Preservative	2	200	

Table 1B (continued)

RL, reporting level; DF, detection frequency; NA, not analyzed; -, no data; Y, yes; N, no.

a HPLC/MS-ESI(+).

^b LC/MS-ESI(+).

° HPLC/MS-MS-ESI(+).

d GC/MS.

sampling (Stackelberg et al., 2004), which were not time-composited nor preserved with ascorbic acid, and in which 63 of the 106 analytes were measured in unfiltered (whole-water) samples.

Two samples of sludge that settled from prechlorinated source water after coagulation with ferric chloride, and two samples of solids from the backwashing of GAC filters (Fig. 1) were collected in prebaked, 1-L amber glass bottles. Supernatant water was siphoned off the top of the filter-backwash samples after overnight refrigeration, and all wet-solids samples were chilled on ice and sent overnight to participating laboratories.

3. Analytical methods

The water samples were analyzed for 113 compounds, and the sediment samples were analyzed for 71 of these compounds, using methods developed by the USGS (Tables 1A and 1B). Eighteen pharmaceuticals and selected degradates in water samples were measured by solid-phase extraction (SPE) and high-performance liquid chromatography/mass spectrometry positive-ion electrospray ionization [HPLC/MS-ESI(+)] (Tables 1A and 1B) as described in Cahill et al. (2004), and 17 pharmaceuticals and selected degradates were extracted from solids samples by accelerated solvent extraction (ASE) in a manner similar to the approach described in Kinney et al. (2006a). Compounds in these extracts were identified and quantified by the method described in Cahill et al. (2004). 37 antibiotics and selected degradates in water samples were measured by SPE and LC/MS-ESI(+) (Michael Meyer, USGS, written communication, 2005); 14 of these compounds were also measured by HPLC/MS-MS-ESI(+) (Tables 1A and 1B). The HPLC/MS-MS-ESI(+) method also measured a primary degradate of erythromycin (erythromycin-H₂O) (Michael Meyer, USGS, written communication, 2005). 59 other OCs in water samples were measured by SPE and gas chromatography/mass spectrometry (GC/MS) (Tables 1A and 1B) (Zaugg et al., 2002); 54 of these OCs also were extracted from solids samples through ASE, as described in Burkhardt et al. (2005) and identified through the method described in Zaugg et al. (2002).

Sixteen OCs in water samples were measured by 2 analytical methods (Tables 1A and 1B). The presence or absence of these compounds was confirmed in all of the paired determinations for 11 of these compounds (ciprofloxacin, cotinine, erythromycin, norfloxacin, sarafloxacin, sulfachloropyridazine, sulfadiazine, sulfadimethoxine, sulfamethoxazole, trimethoprim, and tylosin); and in 98.6% of the paired determinations for sulfamethazine, and 97.2% of the paired determinations for caffeine, lincomycin, ofloxacin, and sulfathiazole. Of these 16 compounds, 14 are antibiotics that were measured by LC/MS–ESI(+) and HPLC/MS–MS–ESI (+). The latter (MS–MS) method is the more sensitive,

and achieves a lower RL, therefore, data from the MS– MS method were used to describe the occurrence and concentration of these antibiotics through the treatment process. Two of the compounds (cotinine and caffeine) were measured by HPLC/MS–ESI(+) and GC/MS; the mean percent recovery for cotinine by the HPLC/MS– ESI(+) method was greater than by the GC/MS method (Cahill et al., 2004; Zaugg et al., 2002); therefore, the data from the HPLC/MS–ESI(+) method were used to describe the occurrence and concentration of cotinine through the treatment process. Mean percent recoveries for caffeine by the HPLC/MS–ESI(+) method were not reported by Cahill et al. (2004), therefore, occurrence and concentration of caffeine through the treatment process are described by data from the GC/MS method.

Analytes detected at low concentrations were assigned estimated values in accordance with conventions described in Oblinger Childress et al. (1999) rather than being censored (set to nondetection) at higher RLs. Providing estimates of low concentrations for analytes that are qualitatively identified by mass spectral methods allowed computation of the average percent removal of these compounds through the DWT process needed for this research (Stackelberg et al., 2006).

Six field blanks and 86 laboratory blanks were analyzed

for target compounds. Blank samples were derived from

4. Quality assurance

laboratory-grade organic-free water. Field blanks were used to indicate whether sampling procedures, sampling equipment, field conditions, or sample-shipment procedures introduced target compounds into environmental samples, and laboratory blanks were used to assess the potential for sample contamination in the laboratory. Field blanks were collected at each of the six water-sampling sites (Fig. 1). Six compounds (pyrene, fluoranthene, carbamazepine, acetaminophen, dehydronifedipine, and DEET) were each detected in one field blank and censored in the associated environmental samples, and two compounds (triphenyl phosphate and cotinine) were detected in one field blank, but not in the associated environmental sample and, thus, were not censored. One compound (NP₂EO) was detected in 10 laboratory blanks, and detections of NP₂EO in associated environmental samples that were less than 3 times the concentration measured in the laboratory blanks were censored. Two compounds (metformin and acetaminophen) were detected in one laboratory blank. Metformin was not detected in the associated environmental samples and, thus, was not censored; but acetaminophen was detected in one environmental sample at a concentration less than 3 times the laboratory blank concentration, and was censored.

At least one laboratory-reagent spike was processed with each set of 10 environmental samples during this study. Recoveries ranged from 15% for dichlorvos to 183% for 5-methyl-1*H*-benzotriazole, with a median recovery of 92% for all compounds. Matrix spike



Fig. 2. Compounds detected in 25% or more of source-water samples.

recoveries were not specifically determined in this study; although, matrix spike-recovery samples are collected for a larger USGS research effort, of which this study is a part (Stackelberg et al., 2006). Average recoveries and standard deviations for matrix-free

reagent spikes are similar to those for matrix spikes, even though many matrix samples are from complex wastewater-effluent samples; this indicates that the analytical methods for these compounds were reliable even in the presence of complex interferences.



Fig. 3. Compounds detected in 25% or more of source-water samples or in solids samples at 100 μ g/kg or greater.

			-
Ta	h	P	2

Compounds detected in solids samples or in at least 25% of source-water samples

Constituent	Log	Water	Average concentration (water: µg/L; solids: µg/kg)									
	K _{ow}	solubility	Source	Clarified	Disinfected	Filtered	Finished	Percent				
	(20– 25 °C)	(mg/L at 25 30 °C)	Water	Water/solids	Water	Water/solids	Water	Removal				
Pharmaceuticals				<u></u>								
Erythromycin-H ₂ O		-	0.01	0.0053/NA	0.0004	ND/NA	ND	100				
Sulfamethoxazole	0.89	610	0.030	0.020/ND	ND	ND/ND	ND	100				
Acetaminophen	0.46	14,000	0.015	0.006/ND	ND	0.001/ND	.0003	98				
Caffeine	-0.07	21,600	0.126	0.126/ND	0.116	0.004/ND	0.015	88				
Carbamazepine	2.45	17.7	0.191	0.186/54	0.149	0.004/359	0.029	85				
Cotinine	0.07	998,600	0.008	0.0071/ND	0.010	0.0007/ND	0.003	57				
Dehydronifedipine	-		0.001	0.0007/ND	0.0006	ND/ND	0.0006	40				
Fluoxetine	4.05	60.3	ND	ND/49.5	ND	ND/58.6	ND	NC				
Diphenhydramine	3.27	3060	ND	ND/26.2	ND	ND/ND	ND	NC				
Detergent degradates												
OP1EO	6.02	****	0.079	0.0783/65	ND	ND/ND	ND	100				
NP ₂ EO	5.3		1.192	0.858/1940	0.592	ND/785	0.192	84				
OP ₂ EO	>4.5		0.038	0.017/ND	0.015	ND/ND	0.010	74				
NP	5.92	5000	0.342	0.342/185	0.100	0.108/160	0.092	73				
Flame retardants and plastic	cizers											
TPP	4.59	1.9	0.049	0.049/27.5	0.069	ND/27	ND	100				
TBEP	3.75	1100	0.357	0.294/525	0.309	ND/545	ND	100				
TCEP	1.44	7000	0.095	0.094/ND	0.092	ND/ND	0.004	96				
TDIP	3.65	7	0.102	0.102/109	0.101	ND/84.5	0.012	88				
Bisphenol A	3.32	120	0.107	0.108/19	0.045	.014/ND	0.026	76				
TBP	4	280	0.048	0.027/14.5	0.054	ND/7.5	0.015	69				
Polycyclic aromatic hydroca	urbons											
Anthracene	4.45	0.043	0.010	0.014/30.5	ND	ND/31.5	ND	100				
Fluoranthene	5.16	0.26	0.041	0.044/215	0.031	ND/205	ND	100				
Phenanthrene	4.46	1.15	0.018	0.017/135	0.015	ND/145	ND	100				
Pyrene	4.88	0.135	0.037	0.041/136	0.014	ND/99.5	ND	100				
Benzo[a]pyrene	6.13	01002	ND	ND/48.5	ND	ND/15	ND	NC				
Naphthalene	3.3	31	ND	ND/27.5	ND	.004/39.5	ND	NC				
2-Methylnaphthalene	3.86	25	ND	ND/20	ND	ND/22	ND	NC				
I-Methylnaphthalene	3.87	26	ND	ND/18.6	ND	ND/17.5	ND	NC				
2,6-Dimethylnaphthalene	4.31	2	ND	ND/19.3	ND	ND/14	ND	NC				
Fragrances and flavorants												
HHCB	5.9	1.75	0.069	0.069/41.5	0.073	ND/39	ND	100				
AHTN	5.7	1.25	0.126	0.128/92	0.105	0.014/83	0.036	71				
Camphor	3.04	1600	0.004	0.006/ND	0.006	0.001/ND	0.003	25				
Skatol	2.6	498	ND	0.001/129.5	ND	ND/53.5	ND	NC				
Plant and animal steroids												
b-Sitosterol	9.65		0.411	0.258/4000	0.142	ND/2900	ND	100				
b-Stigmastanol	9.73		0.325	0.267/1270	0.167	ND/650	ND	100				
Cholesterol	8.74	0.1	0.670	0.369/7100	0.288	ND/6050	ND	100				
Pesticides, repellents, adjuv	ants											
Carbaryl	2.36	110	0.055	0.056/NA	0.035	ND/NA	ND	100				
Carbazole	3.72	1.8	0.024	0.020/34.5	0.008	ND/36.5	ND	100				
Diazinon	3.81	40	0.047	0.031/ND	ND	ND/ND	ND	100				
Metolachlor	3.13	530	0.046	0.033/ND	0.037	ND/ND	ND	100				
DEET	2.18	912	0.120	0.13/11	0.125	0.071/17	0.078	35				
Indole	2.14	3560	ND	0.001/186.5	ND	ND/59	ND	NC				

(continued on next page)

Constituent	Log	Water	Average concentration (water: µg/L; solids: µg/kg)										
	K_{ow}	solubility (mg/L_at	Source	Clarified	Disinfected	Filtered	Finished	Percent					
	(20– 25 °C)	(ing/L) at 25– 30 °C)	Water	Water/solids	Water	Water/solids	Water	Removal					
Miscellaneous													
Anthraquinone	3,39	1.35	0.080	0.088/170	0.098	ND/200	ND	100					
Benzophenone	3.18	137	0.057	0.059/170	0.068	0.006/215	ND	100					
4-Cresol	1.94	21,500	0.011	0.010/305	0.004	ND/195	ND	100					
Tetrachloroethene	3.4	200	0.038	0.032/3.9	0.032	0.007/3.45	0.003	92					
Triethyl citrate	0.33	65,000	0.085	0.080/NA	0.078	0.008/NA	0.013	85					
Isophorone	1.7	12,000	ND	ND/12	ND	ND/6.5	ND	NC					
Triclosan	4.76	10	ND	ND/27	ND	ND/15.5	ND	NC					

Table 2 (continued)

NC: not calculated; ND: not detected; >, greater than; -, no data.

Table 3						
Tukey's multiple comparison test	groupings for	compounds	detected in a	t least 50)% of source-	water samples

Constituent	Tukey's multiple comparison test groupings											
	Source	Clarified	Disinfected	Filtered	Finished							
Pharmaceuticals		·			1994 <u>,</u>							
Erythromycin-H ₂ O	А	А	В	В	В							
Sulfamethoxazole	А	А	В	В	в							
Acetaminophen	А	А	В	В	в							
Caffeine	А	А	А	В	В							
Carbamazepine	А	А	А	В	В							
Cotinine	Α	AB	А	С	BC							
Flame retardants and plastic	izers											
ТРР	А	А	А	В	В							
ТВЕР	А	А	А	В	В							
TCEP	А	А	А	В	В							
TDIP	А	А	А	В	В							
Bisphenol A	AB	А	AB	В	AB							
Polycyclic aromatic hydrocar	·bons											
Fluoranthene	А	А	А	В	В							
Phenanthrene	А	А	А	В	В							
Pyrene	А	А	BC	С	С							
Fragrances and flavorants												
ннсв	А	А	А	В	в							
AHTN	А	А	А	В	В							
Pesticides, repellents, adjuva	nts											
Carbaryl	А	AB	AB	В	В							
Diazinon	А	AB	В	В	В							
Metolachlor	А	AB	AB	В	В							
DEET	А	А	А	В	В							
Miscellaneous												
Anthraquinone	А	А	А	В	В							
Benzophenone	A	A	A	B	B							
Tetrachloroethene	A	A	A	BC	ē							
Triethyl citrate	А	A	А	B	В							

Sampling locations with one or more letters in common do not differ significantly from one another.

5. Data analysis

Analysis of variance (ANOVA) on ranked concentrations was used to evaluate the null hypothesis that mean ranked concentrations were statistically similar among the six sampling points. If the null hypothesis was rejected, Tukey's multiple comparison test was used to indicate which mean ranked concentrations were similar to or significantly different from others (Helsel and Hirsch, 1992). Significance was set at the 95% confidence level for all statistical tests.

Average percent removal by each water-treatment process was calculated for selected OCs by the formula $(1 - [C/C_o] \times 100)$, where C is the average concentration in effluent over twelve 24-h sampling periods from the treatment step, and C_o is the average concentration in effluent from the preceding treatment step. Total average percent removal was calculated with C as the average concentration in finished water over twelve 24-h sampling periods, and C_0 the average concentration in source water. Nondetections were set equal to zero for these calculations. Analytical precision associated with trace concentrations may affect the precision of average concentrations and, thus, calculations of their percent differences; therefore, average percent differences in the concentration of OCs between treatment steps are grouped into three categories in the discussions that follow: (1) low (<25% difference), (2) moderate (25-75% difference), and (3) high (>75% difference).

6. Results

The effectiveness of a DWT plant in degrading or removing OCs depends on several factors (some of which may change through time), including the quality of the source water, the type and mode of operation of each treatment process, and physiochemical characteristics of the compounds themselves (Volk et al., 2005; Coupe and Blomquist, 2004). The flow of one of the two source streams ranged from about 6 to more than $81 \text{ m}^3/$ s during the sample collection period and the concentrations of some compounds increased during high flows, whereas the concentration of others decreased (Kolpin et al., 2004). Turbidity, a measure of suspendedsediment concentration, ranged from 7.5 to 22.9 NTU in source waters and averaged 11.3 NTU during the 3week sample collection period. Results presented here pertain only to the source-water characteristics during the sample collection period and the specific manner in which the plant was operated during this time.

The 56 compounds that were detected in sourcewater or solids samples are listed in Table 1A; the 57 compounds that were not detected are listed in Table 1B. The following sections focus on the average concentration of OCs through the treatment processes, and their occurrence in finished water. To maximize the useful scientific information in our dataset and to improve our understanding of the fate of each OC through the DWT process, the detection frequencies and average concentrations reported for each compound are based on all detections (Stackelberg et al., 2006). Direct comparisons of detection frequencies or average concentrations for OCs with differing RLs, however, would be inappropriate (Table 1A).

ANOVA on ranked concentrations indicates that concentrations of OCs in the source-water and sourceand-recycled water samples were statistically similar; therefore, results from the source-and-recycled samples are not discussed further. Furthermore, statistically significant differences in ranked concentrations could be calculated only for OCs that were detected in at least 50% of source-water samples; therefore, ANOVA results are not shown for OCs detected in fewer than 50% of source-water samples.

6.1. OCs in source water

The detection of 45 of the 113 OCs in at least 1 sample of source water, and of 32 of these compounds in at least 25% of source-water samples (Fig. 2), is consistent with previous reports of the frequent occurrence of OCs in streams that receive effluent from STPs (Glassmeyer et al., 2005; Kolpin et al., 2002). Compounds detected in at least 75% of the source-water samples include polycyclic musk fragrances (AHTN, HHCB), pharmaceuticals and their degradates (carbamazepine, acetaminophen, cotinine, sulfamethoxazole, and caffeine), the insect repellent N,N-diethyltoluamide (DEET), organophosphorus flame retardants and plasticizers [tris(2butoxyethyl) phosphate (TBEP), tris(2-chloroethyl)phosphate (TCEP), tris(dichloroisopropyl) phosphate (TDIP), and triphenyl phosphate (TPP)], polycyclic aromatic hydrocarbons (PAHs) (fluoranthene, pyrene, phenanthrene), the solvent tetrachloroethene, and the cosmetics triethyl citrate and benzophenone. The concentrations of these frequently detected compounds in source waters were generally low, however, and rarely exceeded 1 µg/L (Fig. 2). A few specific compounds, e.g., TBEP, 4nonylphenol (NP), and cholesterol, the latter two of which were detected in fewer than half of the source-water samples, account for a large percentage of the total measured concentration of all target analytes (Fig. 2); this underscores the importance of collecting multiple samples over differing flow conditions to adequately reflect the source-water quality. Certain compounds within specific OC categories accounted for a large percentage of the total average concentration for those categories. For example, carbamazepine and caffeine accounted for most of the total average concentration of pharmaceuticals, NP₂EO and NP accounted for most of the detergent metabolite concentration, TBEP accounted for most of the flame retardants and plasticizer concentration, AHTN and HHCB accounted for most of the fragrances and flavorant concentration, and DEET accounted for most of the pesticides and repellent concentration (Fig. 3).

6.2. Removal through treatment processes

In general, the hydrophobic compounds (as indicated by high log K_{ow} and low solubility), such as PAHs and plant and animal steroids, were detected at elevated concentrations in dried-solids samples and were not present at measurable concentrations in finished-water samples. In contrast, the hydrophilic compounds (as indicated by low log K_{ow} and high solubility), such as pharmaceuticals, were detected at relatively low concentrations in dried-solids samples and were present in measurable concentrations in finished-water samples. Detection frequency and concentration of OCs in the solids and water phases are highly variable relative to their log K_{ow} and water-solubility values, however, as a result of differences in (1) the capability to measure individual OCs in solids and (or) water matrices, (2) the manner in which individual OCs react to each treatment process, and (or) (3) the use of individual OCs in the watershed. Also, predictors of water-solid distributions, such as log K_{ow} , assume that water and solids are in equilibrium, which may not be true in a dynamic DWT process. The following discussion focuses on the clarification, disinfection, and GAC-filtration treatments - the primary processes that govern the fate of OCs through the treatment process, and how the effectiveness of these steps varies among and within the eight classes of compounds. Average concentrations in water and solids samples are presented in Table 2 and shown in Fig. 3.

6.3. Clarification

Clarification consists of chemically treating the source water to destabilize colloidal particles (coagulation) and facilitate their flocculation and settling with other suspended sediments. Sulfuric acid (H_2SO_4) was added to the source waters prior to clarification to optimize pH levels in the 4.5–5.5 range, and ferric chloride (FeCl₃) was added as the coagulant agent. Injection of microsand into the clarification tanks to enhance flocculation and settling resulted in retention times of 15–20 min for the clarification process. Two clarification tanks were operated in parallel during this study; the samples of clarified water were collected subsequent to one of these tanks.



Fig. 4. Compounds detected in 1 or more samples of finished water.

In general, clarification accounted for only 15% of the reduction in average concentration of OCs during the treatment process. Each of the 32 OCs detected in 25% or more of source-water samples (Fig. 2) were also detected in clarified effluent – an indication of incomplete degradation or removal. Ranked concentrations for OCs detected in at least 50% of source-water samples did not differ significantly between source- or clarified-water samples (Table 3), and none of these 32 OCs showed a decrease of 75% or more in average concentration after clarification (Table 2). Clarification, therefore, is generally not a primary route by which OCs in filtered-water samples are degraded or removed.

Clarification decreased the average concentration of eight OCs (sulfamethoxazole, acetaminophen, dehydronifedipine, OP₂EO, TBP, cholesterol, diazinon, and metolachlor) by 25% to 75% of their concentration in source water - an indication of moderate degradation or removal (Fig. 3). Five of these compounds (OP₂EO, TBP, cholesterol, diazinon, and metolachlor) are hydrophobic, two of which (TBP and cholesterol) were detected in the dried solids of settled sludge; the high average concentration of 7100 µg/kg for cholesterol (log K_{ow} =8.74) indicates removal by partitioning onto suspended solids or ferric hydroxide precipitates. The other three of these eight compounds (sulfamethoxazole, acetaminophen, and dehydronifedipine) are hydrophilic (log $K_{ow} < 1.0$) and, as a result, were not detected in the dried solids of settled sludge. The moderate removal of these hydrophilic pharmaceuticals from the water phase during clarification may be explained by ferric chloride coagulation, which results in base or acid hydrolysis; the potential importance of this removal mechanism could not be verified, however, because the degradates that are potentially formed through hydrolysis were not measured during this study.

The average concentrations of 24 of the 32 OCs that were detected in at least 25% of source-water samples were less than 25% lower in clarified effluent than in source waters - an indication of poor degradation or removal. Minor removal of 10 of these compounds (carbamazepine, caffeine, erythromycin-H2O, DEET, TCEP, fluoranthene, pyrene, phenanthrene, metolachlor, and HHCB) is consistent with laboratory-scale simulations of the effect of chemical treatments on these compounds (Ternes et al., 2002; Westerhoff et al., 2005). The analyses of clarified samples in this study provides new information on the limited degradation or removal of additional pharmaceuticals (cotinine), detergent metabolites (NP₂EO and NP), flame retardants and plasticizers (TBEP, bisphenol A, TDIP, and TPP), the plant sterol *β*-stigmastanol, and the miscellaneous

compounds triethyl citrate, anthraquinone, benzophenone, tetrachloroethene, and 4-cresol by this process. Several of these OCs (including NP₂EO, β -stigmastanol, TBEP, and 4-cresol) that were not substantially decreased in the water phase, were detected in the dried solids of settled sludge – a reflection of their hydrophobic nature and their adsorption to suspended sediments. Another 27 OCs that were not substantially decreased in the water phase, or that were not detected in source-water samples, were detected in the dried solids of settled sludge – a further indication of their undetected presence in filtered samples of source waters through sorption to suspended sediments (Table 2).

6.4. Disinfection

The clarified water was disinfected through the addition of sodium hypochlorite (NaClO) to inactivate pathogenic microorganisms (Fig. 1). Contact time for primary disinfection was generally 200 to 300 min. Disinfected-water samples represent water composited from both disinfection basins that were in operation during this study.

In general, disinfection accounted for 32% of the degradation or removal of OCs from the water phase. Of the 32 OCs that were detected in 25% or more of sourcewater samples and in clarified-effluent samples, 4 (sulfamethoxazole, acetaminophen, erythromycin-H₂O, and diazinon; Tables 2 and 3) had ranked concentrations that were significantly lowered in disinfected effluent, or average concentrations that decreased by at least 75%, from the values in clarified effluent; this is attributed to reaction with free chlorine. Substantial loss of the first three of these compounds through oxidation with free chlorine is consistent with laboratory-scale simulations of their fates through the disinfection process (Bedner and MacCrehan, 2006; Westerhoff et al., 2005; Dodd and Huang, 2004), and the substantial loss of the fourth (diazinon) corroborates findings of Coupe and Blomquist (2004), Magara (1994), and Aizawa et al. (1994). Chlorinated byproducts likely to form during the reaction of these compounds with NaClO (Pinkston and Sedlak, 2004; Coupe and Blomquist, 2004) were not measured in this study.

Chlorination decreased the average concentration of seven of these 32 OCs (NP, bisphenol A, fluoranthene, pyrene, carbaryl, carbazole, and 4-cresol) by 25% to 75% relative to the concentration in clarified effluent – an indication of moderate reactivity with free chlorine (Table 2; Fig. 3). Loss of two of these seven compounds (NP and bisphenol A) through oxidation with free

chlorine corroborates the findings of Deborde et al. (2004), Petrovic et al. (2003), and Hu et al. (2002a,b). Additional chlorinated byproducts likely form during reaction of NP and bisphenol A with NaClO (Korshin et al., 2006; Petrovic et al., 2003; Hu et al., 2002a,b) but were not measured during this study. Loss of fluor-anthene and pyrene corroborates research by Westerhoff et al. (2005) although the effectiveness of oxidation for fluoranthene is less than reported from that study. Data from the present study provide new information on moderate removal or degradation of carbaryl, carbazole, and 4-cresol through oxidation with free chlorine.

The average concentrations of another 21 of the 32 OCs that were detected in 25% or more of source-water samples were decreased by less than 25% in disinfected effluent in relation to clarified effluent - an indication of little or no reactivity of these compounds with free chlorine under ambient pH conditions of the disinfection process. For example, the pharmaceuticals carbamazepine, caffeine, cotinine, and dehydronifedipine were found to have low reactivity with free chlorine which corroborates the findings of Gibs et al. (2007) who examined the stability of OCs in the presence of a free chlorine residual as a function of time. Other investigators (Westerhoff et al., 2005) report more effective oxidation of carbamazepine and caffeine, possibly due to differences in experimental conditions. The decrease in average concentration of five organophosphorus flame retardants (TBEP, TDIP, TCEP, TPP, and TBP), the musk fragrances AHTN and HHCB, the insect repellent DEET, and the pesticide compound metolachlor was less than 25% through oxidation with free chlorine which is consistent with laboratory-scale simulation of the fate of several of these OCs through disinfection with NaClO (Westerhoff et al., 2005). Eight other OCs that were not effectively oxidized by free chlorine in this study were OP₂EO, phenanthrene, camphor, cholesterol, triethyl citrate, anthraquinone, benzophenone, and tetrachloroethene.

6.5. GAC filtration

Chlorinated water from the disinfection process was passed through filters that contained 25.4 cm of sand and 91.4 cm of bituminous granular activated carbon (GAC filters) to retain remaining fine particles and bacteria and to control taste- and odor-causing compounds. Contact time on the GAC filters was generally 1.5 to 3 min. Eight GAC filter banks were in simultaneous operation during this study; samples of GAC-filtered water were collected subsequent to one filter bank.

Despite the short filter-contact times, GAC filtration accounted for 53% of the removal of OCs from the water phase. Of the 29 OCs that were detected in at least 25% of source-water samples and in disinfected effluent, 25 had ranked concentrations that were significantly decreased, and average concentrations that were decreased by 75% or more (Tables 2 and 3), corroborating previous documentation of the effectiveness of GAC filtration in removing OCs from the water phase (Ternes et al., 2002). This process also lowered the concentrations of many OCs - the pharmaceutical degradates erythromycin-H₂O and dehydronifedipine, the detergent metabolite OP₂EO, each of the five organophosphorus flame retardants (TBEP, TDIP, TCEP, TPP, and TBP), the three PAHs, i.e. fluoranthene, pyrene, and phenanthrene, the musk fragrance HHCB, the sterol cholesterol, and the five pesticides, i.e. carbaryl, metolachlor, and carbazole, and anthraquinone and 4-cresol - to below analytical detection limits. Average concentrations of carbamazepine, caffeine, cotinine, triethyl citrate, and benzophenone were decreased by 90% or more, and average concentrations of AHTN, camphor, and tetrachloroethene were decreased by 87%, 83%, and 78%, respectively.

GAC filtration decreased the average concentration of two OCs that were detected in at least 25% of sourcewater samples and in disinfected effluent (bisphenol A and DEET) by 25% to 75%, an indication of moderate removal. Only one compound (NP) showed no response to GAC filtration, an indication of either ineffective removal of NP from the water phase through GAC filtration, or the continuing formation of NP through the break down of NPEOs through the treatment process (Petrovic et al., 2003).

Removal of OCs by GAC filtration was substantiated by the occurrence of 32 compounds in the dried solids of filter-backwash sediments (Table 2). The most hydrophobic compounds (cholesterol, *B*-sitosterol, and β -stigmastanol; log $K_{ow} > 8$) were detected at average concentrations of 6050, 2900, and 650 µg/kg, respectively, and NP₂EO (log K_{ow} =5.3), TBEP (log K_{ow} =3.75) and carbamazepine (log K_{ow} =2.45) were detected at average concentrations of 785, 545, and 359 µg/kg, respectively (Fig. 3). Eight OCs that were not detected in samples of source water were detected in the dried solids of filter-backwash sediments (fluoxetine, benzo[a]pyrene, naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, 2,6-dimethylnaphthalene, skatol, isophorone, and triclosan) (Table 2); this indicates their presence in sourcewater supplies during time periods not sampled during this study.

6.6. Finished water

During this study, GAC-filtered water was diverted to a clear well to which NaClO was added to maintain a chlorine residual of about 1.2 mg/L through the distribution system. Finished-water samples were collected after the clear well and represent the quality of water leaving the treatment plant and entering the distribution system (Fig. 1).

The detection of 21 compounds in at least one sample of finished water, despite the general decrease in average concentration of OCs from source to finished waters, is an indication of incomplete degradation or removal through the treatment process (Fig. 4). Of these 21 compounds, only tetrachloroethene (detected once) is currently regulated in drinking-water supplies. Carbamazepine and DEET were detected in every sample of finished water, and cotinine and AHTN were detected in 75% and 50% of finished-water samples, respectively. Several compounds that were not detected in samples of source water were detected in samples of finished water (for example, cimetidine, diltiazem, and diphenhydramine). One explanation may be their intermittent occurrence in source waters with (1) recycling of OCs that were absorbed on GAC and released during backwashing, (2) desorption from GAC during equilibration with aqueous-phase concentrations, or (3) saturated GAC that does not allow adsorption. Another potential explanation is differing percent recoveries for these compounds in source-water versus finished water matrixes. Several other compounds were detected at higher average concentrations in finished water than in GAC-filtered water. One explanation could be that GAC-filtered samples were collected from only one of eight operating filter banks. The effectiveness of GACfilter banks in removing OCs depends on the age and condition of the GAC; therefore, effluent from one filter bank might not represent the chemical quality of water composited from all eight filter banks.

Concentrations of individual compounds in finished water were low and mostly less than 0.5 μ g/L. Tetrachloroethene was detected at 0.03 μ g/L; more than 160 times less than its USEPA MCL of 5 μ g/L. Only the detergent--metabolite compound NP was detected at concentrations exceeding 1 μ g/L. The majority of the total measured concentration of OCs in finished water represented five compounds (NP, DEET, AHTN, carbamazepine, and BPA) (Fig. 4). The infrequent detection of several of these compounds underscores the need for collection of multiple samples to adequately characterize the quality of finished water.

7. Discussion

Results of this study indicate that the combined water treatments (clarification, disinfection, and GAC filtration) were effective at degrading or removing many OCs from source-water supplies to concentrations below analytical detection. Of the 32 compounds that were detected in at least 25% of the source-water samples (Fig. 2), 16 were not detected in samples of finished water (100% degradation or removal), and seven (carbamazepine, caffeine, acetaminophen, bisphenol A, triethyl citrate, TDIP, tetrachloroethene, and TCEP) underwent a 75% or greater decrease in average concentration from source to finished water (Table 2). The most persistent compounds were camphor and DEET, with 25% and 35% removal, respectively. In general, GAC filtration accounted for 53% of the removal of OCs from the water phase, disinfection accounted for 32%, and clarification accounted for 15%. These results corroborate other research on the effectiveness of these treatments in removing OCs from source waters (Ternes et al., 2002; Westerhoff et al., 2005). Results of this study indicate wide variability in the effectiveness of each treatment among and within OCs categories. The primary route of removal for hydrophobic analytes (log K_{ow} values>4) that were detected in source waters (e.g., plant and animal steroids, fragrances and flavorants, detergent degradates, and PAHs) was adsorption on GAC, although some hydrophobic compounds were oxidized by free chlorine during disinfection and, thus, unavailable for adsorption on GAC (for example, OP1EO, anthracene, diazinon, Dlimonene). The most hydrophilic class of compounds detected in source waters was pharmaceuticals (median log $K_{ow} < 1$) many of which reacted with free chlorine. GAC filtration removed most of those that were not oxidized by free chlorine (for example, caffeine and cotinine), as well as the most hydrophobic pharmaceutical detected in source waters (carbamazepine; log K_{ow} =2.45). These findings are for filtered samples of effluent from the clarification, disinfection, and GACfiltration processes. Findings from studies utilizing whole-water (unfiltered) samples from these processes may differ because the amount of suspended solids is significantly reduced through the DWT process.

The detection of 21 compounds in 1 or more samples of finished water (Fig. 4), and from 3 to 13 of these compounds per sample, indicates incomplete removal or incomplete degradation during the water-treatment process. Of these 21 compounds, only tetrachloroethene is currently regulated in drinking-water supplies. By monitoring the occurrence of unregulated contaminants in a drinking-water supply, this study provides valuable information for potential inclusion in the USEPA's National Contaminant Occurrence Database and Drinking Water Contaminant Candidate List. Data on unregulated contaminants supports decision-making for future drinking-water regulations and helps establish research priorities and future monitoring needs.

Co-occurrence of compounds (3 to 13 per sample of finished water) is of interest because drinking-water regulations are based on the effects of individual compounds, not combinations of compounds. The detection of the known or suspected endocrine disrupters BPA, NP, OP₂EO, TDIP, and TCEP in finished water could be of concern because the potential human-health effects associated with chronic exposure to trace levels of multiple organic contaminants through routes such as drinking water are poorly understood (Kümmerer, 2001), although Schwab et al. (2005) found no appreciable human-health risk from the presence of trace concentrations of pharmaceuticals in drinking water. The stability of 17 of the 21 compounds detected in samples of finished water in the presence of a free chorine residual was evaluated by Gibs et al. (2007) (data not available for triethyl citrate, cimetidine, diltiazem, and diphenhydramine). Five compounds (acetaminophen, NP, BPA, codeine, and sulfathiazole) showed a greater than 90% reduction in concentration with residual chorine indicating the presence of chlorine is an effective means of their removal or degradation. The concentrations of the remaining 12 compounds decreased by no more than 11% in the presence of a free chlorine residual during residence times typical of this DWT plants distribution system and, thus, these compounds are likely present in delivered water.

The occurrence of OCs in finished water may indicate that drinking water is a source of human exposure. Three of the 21 compounds detected in samples of finished water (AHTN, DEET and cotinine), have been monitored and detected in samples of human blood, milk, or urine (Centers for Disease Control and Prevention, 2005; Hutter et al., 2005; Kurunthachalam et al., 2005). Biomonitoring of these compounds indicates environmental exposure to these chemicals, although that exposure could be from sources other than drinking water (Adolfsson-Erici et al., 2002). Degradates of parent compounds that were not detected in samples of finished water (for example, PAHs) have been detected in human blood or urine (Centers for Disease Control and Prevention, 2005). The detection of OC degradates in body fluids underscores the need to measure a complete suite of parent compounds and their degradates to fully characterize their fate through the DWT process and the potential for exposure through drinking water. Finally, classes of OCs that were detected in finished water (for example, pharmaceuticals, detergent degradates, flame retardants and plasticizers, and fragrances and flavorants) could be candidates for future biomonitoring to assess environmental exposure.

The dried solids of settled sludge and filter-backwash sediments were found to contain 34 OCs. Residual sludge from this DWT plant is transported to a nearby STP for disposal; although residual sludge from many STPs and DWT plants is digested, dewatered, and used as a soil amendment, especially in agricultural areas. Previous research has documented the potential for certain OCs to leach from sludge-amended soils to streams and ground water (Kinney et al., 2006b; Jacobsen et al., 2005; Xia et al., 2005; Diffrancesco et al., 2004; LaGuardia et al., 2001; Oppel et al., 2004). Additional research is needed to more fully characterize this potential for a broader suite of constituents such as examined in this study.

Acknowledgements

This study was conducted cooperatively between the U.S. Geological Survey and the New Jersey Department of Environmental Protection. The authors thank the operators and staff of the drinking-water-treatment plant for allowing access to their facility and assisting our needs. We also thank Richard Coupe and Gregory Delzer of the U.S. Geological Survey and a anonymous reviewer for their helpful comments and suggestions.

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Memorandum



Date:	November 1, 2018
То:	Buckman Direct Diversion Board
From:	Nancy R. Long
Subject:	Consideration of Amendment No. 8 to the PMFSA

ITEM AND ISSUE:

Discussion and possible action to approve Amendment No. 8 ("Amendment") to the Project Management Fiscal Services Agreement ("PMFSA") to: provide a new definition for the Las Campanas entities; align the financial statements/audit deadline with the City's schedule; increase the Project Manager's fee from 1% to 4.5%; and provide input from the Board in the selection and employment of the Facilities Manager.

BACKGROUND AND SUMMARY:

A staff advisory committee recommended that the Buckman Direct Diversion Board ("BDDB") select the City of Santa Fe to continue to serve as Project Manager for the BDDB and enter into a new agreement for operations and fiscal support. The BDDB adopted the committee's recommendation. The current PMFSA is continuing in effect on a month to month basis.

In order to facilitate the finalization of a new agreement, the BDDB has reconstituted the staff committee and included the Chair and Vice Chair of the BDDB on the committee.

As the committee works through the terms of a final proposed agreement, it is recommending that an amendment to the current PMFSA be approved while the remaining terms of the agreement can be worked through. In addition, the Amendment includes provisions to change the definition of "Las Campanas" from the prior limited partnership to the Club and the Coop, deletes the requirement for the financial statement/audit deadline as 90 days after the end of the fiscal year which did not comport with the City's audit deadline and allows for Board input in the selection and employment of the Facilities Manager.

ACTION REQUESTED:

It is recommended that the Board approve Amendment No. 8 to the PMFSA. The Amendment must also be approved by the City Council and the Board of County Commissioners.





Memorandum



Buckman Direct Diversion

Date:	November 1, 2018
То:	Buckman Direct Diversion Board
From:	Mackie M. Romero, BDD Financial Manager
Subject:	BDD Vehicle Replacement Policy

ITEM AND ISSUE:

Request for approval of the Buckman Direct Diversion Vehicle Replacement Policy.

BACKGROUND AND SUMMARY:

In 2014 the Buckman Direct Diversion Board adopted the BDD Major Repair and Replacement Fund Policy. This policy establishes the resources needed to assure the BDD's ability to cover the repair and replacement cost of capital assets already in existence with the BDD.

As part of this policy the BDD has begun work on the BDD Capital Asset Management Plan, utilizing the SAMS program (Sampling and Monitoring System). This program is a working software that requires input from staff to allow meaningful real time inputs related to critical replacement needs, prioritization and costs.

The purpose of this policy is to provide procedures for evaluating vehicles that have been identified as candidates for replacement. This policy is a sub-section of the Major Repair and Replacement Fund Policy and the intent is to continue to define all the assets owned by the BDD to establish a more inclusive policy with distinct replacement values and cycles.

BDD has entered its vehicle fleet into the program with a tiered replacement schedule, which has been included as example of the replacement cycle needed over a 20 year period.

ACTION REQUESTED:

Staff recommends approval of the BDD Vehicle Replacement Policy.

Approved by BDDB November 1, 2018

Councilor Peter Ives, BDDB Chair





Funding / Replacement Cycle

By Fiscal Year

Current Asset Label	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	Total
55176 - 2011 Ford Ranger 4x4 Supercab	37,000								42,000							47,000					126,000
55177 - 2011 Ford Ranger 4x4 Supercab	37,000								42,000							47,000					126,000
55180 - John Deere Gator TS		58,000															63,000				121,000
55164 - 2008 Ford F-250 Supercab 4x4		37,000								42,000								47,000			126,000
55178 - 2011 Ford F350 4x4 S-Duty		60,000								65,000								65,000			190,000
55170 - 2011 Nissan Xterra 4x4			37,000										42,000								79,000
55171 - 2011 Nissan Xterra 4x4			47,000										52,000								99,000
55169 - 2011 Dodge Ram 4x4				37,000										42,000							79,000
55181 - 2011 Dodge Ram Crew Cab				37,000										42,000							79,000
55167 - 2011 Chevrolet Silverado 1500					37,000											42,000					79,000
55184 - 2014 Dodge Ram 1500					36,000								41,000			42,000					119,000
55174 - Catapilar Backhoe									85,000												85,000
55600 - 2016 Kenworth T370																			215,000		215,000
Grand Total	74,000	155,000	84,000	74,000	73,000	•	-	-	169,000	107,000	[-	-	135,000	84,000	-	178,000	63,000	112,000	215,000		1,523,000

Buckman Direct Diversion

Vehicle Replacement Policy

This policy is a sub-section of the BDD Major Repair and Replacement Fund (MRRF) Policy and is intended to implement procedures to manage funding and replacement cycles of the BDD Vehicle Fleet, which have been identified as a capital asset.

In accordance with the Major Repair and Replacement Fund Policy, any equipment costing over five thousand dollars (\$5,000) with a life expectancy of more than three years shall be classified a Capital asset item. All capital asset items shall be recorded in the Buckman Direct Diversion Capital Asset Management Program, SAMS (Sampling and Monitoring System).

The purpose of this policy is to provide procedures for timely replacement, funding and disposal of the BDD Vehicle Fleet.

Replacement Cycle:

In each fiscal year a replacement schedule shall be retrieved from the SAMS program to determine the number of vehicles identified as candidates for replacement. Each vehicle shall be evaluated by the BDD Maintenance Superintendent to determine its condition, age, mileage, maintenance and replacement cost. All these factors shall be considered in determining whether a vehicle should be replaced or extended.

Condition: A physical evaluation will be conducted and documented to determine if the vehicle meets or exceeds base standards.

Age: Is based on years of usage and national averages.

Mileage: Is based on the manner in which the vehicle is operating in and national averages.

Maintenance Costs: Conditions are the cost of repair versus current value.

Replacement Funding:

Funds shall be budgeted from the Major Repair and Replacement Fund upon BDD Board approval and authorization in accordance with the MMRF Policy.

Vehicle Disposal:

Vehicles that have been approved for replacement shall be classified as obsolete personal property and shall follow the procedures established in the BDD Disposal Policy.

Approved by BDDB November 1, 2018

Councilor Peter Ives, BDDB Chair





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Memorandum



Buckman Direct Diversion

Date:	November 1, 2018
То:	Buckman Direct Diversion Board
From:	Mackie M. Romero, BDD Financial Manager
Subject:	2018 Vehicle Replacement Purchase

ITEM AND ISSUE:

Request for approval to purchase two new replacement vehicles, in accordance with the BDD Vehicle Replacement Policy.

BACKGROUND AND SUMMARY:

The Buckman Direct Diversion acquired its current vehicle fleet primarily through the construction phase of the facilities prior to operations. Due to the nature of rugged working conditions, the BDD vehicle fleets are subject to daily wear and tear that has caused these vehicles to deteriorate prior to their intended useful life.

The BDD has formulated a Vehicle Replacement Policy and funding schedule as part of the Major Repair and Replacement Fund Policy to manage funding and replacement cycles of the vehicle fleet.

Through management consideration and the established schedule from the BDD Capital Asset Management Plan, the following vehicles are scheduled to be replaced during the current fiscal year.

- Asset #55176 2011 Ford Ranger 4x4 Super cab
 - o Mileage 39,375
 - Condition Poor/needs replacement
 - Purpose This vehicle is used by the Operations staff to travel to all areas of the plant to verify operation of the water system.

• Asset #55177 - 2011 Ford Ranger 4x4 Super cab

- o Mileage 50,713
- Condition Poor/needs replacement
- Purpose This vehicle is used by the Maintenance staff to haul tools and equipment to various plant locations for repair.

These vehicles will be replaced with (2) two new 2019 Chevrolet Silverado 2500 Crew Cab 4x4, utilizing NM State Price Agreement #70-000-16-00002, for a total cost of \$72,278.00. The estimated useful life of the new vehicles is 8 years.

This request also includes approval of a Budget Amendment Resolution to authorize funds from the Major Repair and Replacement Fund, to cover the cost of this purchase.






August 29, 2018

CITY OF SANTA FE

NEW MEXICO STATE PRICE AGREEMENT #70-000-16-00002 ITEM #12 2019 CHEVROLET SILVERADO 2500 CREW CAB 4X4

Base Price		\$28,974.00
Opt D) Delete Pickup Bed		<150.00>
Opt AX) Spotlight		495.00
Opt AZ) 275 Series Off Road Tires		750.00
Opt BJ) Trailer Tow Package		495.00
Opt BK) Utility Body		<u>5,575.00</u>
	SUB-TOTAL	\$36,139.00
		<u>X2</u>
	TOTAL	\$72,278.00

Log # {Finance use <u>only</u>}:

Batch # {Finance use only }:

City of Santa Fe, New Mexico BUDGET AMENDMENT RESOLUTION (BAR)

DEPARTMENT / DIVISION NAME Buckman Direct Diversion					DATE 11/01/2018	
ITEM DESCRIPTION	BUSINESS	LINE ITEM	SUBSIDIARY {.000000}	SUBLEDGER {0000}	INCREASE	DECREASE
EXPENDITURES					{enter as positive #}	{enter as <u>negative</u> #}
Vehicles < 1.5 Ton	72420	570950	880024		72,278	
REVENUES					{enter as negative #}	{enter as <u>positive</u> #}
BDD City	71420	439960	100		(51,385)	
BDD County	71420	439960	200		(18,048)	
BDD LC Club	71420	439960	300		(1,242)	
BDD LC Coop	71420	439960	400		(1,603)	
JUSTIFICATION: (use additional page if Attach supporting documentation/me	needed) mo				\$0	\$0
To budget fund balance from the	BDD Major I	Repair and R	eplacement F	und 07415.	(Complete section	below if BAR results
Vehicle Replacement Policy					in a net chang	Fund Bal. Increase/
BDDB Approved 11/01/2018					Fund(s) Affected: 07415	(Decrease): (72,278)
					TOTAL:	(3 72 278)
Mackie Romero	11/01/2018	{Use this form	for Finance Com	mittee/		
Prepared By {print name}	Date	City Council		Budget	Officer	Date
		City Council				
Division Director (optional)	Date	Approval Date		Finance	Director {≤ \$5,000}	Date
		Agenda llem #				
Department Director	Date			City Mar	nager (< \$50,000)	Date