December 3, 2012

Mr. Mike Simon
Stationary Source Manager
Air Quality Division
State of Idaho
Department of Environmental Quality
1410 North Hilton
Boise, ID 83706

Dear Mr. Simon:

This letter is in response to your letter dated November 16, 2012. Issues concerning mercury emissions and MBACT analysis were discussed in a previous letter. This letter covers issues concerning F-factor flow calculations and dioxin/furan emission calculations and references. The discussion of F-factor calculations is somewhat lengthy and may be best discussed in person. The dioxin/furan discussion is rather straightforward but the references are dense in content so you may determine they also require further in person discussion.

F-Factor Flow Calculations

Initial submissions of emission calculations were determined using the combustible mass fraction of fuel (MSW+tires) as contributing to the potential emissions. The assumption was that non-combustibles did not contribute to gases exiting the thermal conversion system and therefore were not part of the potential emissions. This assumption resulted in a discrepancy of total daily throughput and heating value of the fuel used by DEQ and Dynamis. After discussion with DEQ engineers it is our understanding that DEQ requests that "as received" fuel mass should be used to determine flow and potential emission outputs. This approach will provide the most straightforward method of measuring and permitting daily fuel throughput regardless of non-combustible content. Additionally, Dynamis has determined that maximum system flows occur during facility's maximum processing capacity (maximum heating value fuel and throughput). These flows result in the maximum pound per hour (lb/hr) emissions. However, maximum-modeled impacts occur during typical/design processing conditions when stack flow is reduced. To estimate worst-case

conditions for both waste throughput and modeled impacts, Dynamis asserts that maximum system processing emission values should be used to calculate facility annual PTE values and as the inputs to model ambient impacts. Typical/design processing flow conditions should be used as the stack exhaust conditions to model ambient impacts. This worst-case approach results in the highest system lb/hr emission values with the lowest stack flow; however, it is used only as a predictor of emissions considering the system cannot run at these conditions. If maximum capacity fuel is used then air input requirements will be large resulting in a stack flow rate higher than typical flow rates and dispersion will improve. Such a condition resulted in one other discrepancy between the initial flow calculation submitted by Dynamis and the value indicated in your letter. The excess air requirements used by DEQ in the calculations of system flow were greatly underestimated resulting in very high combustion temperatures and possible system damage. Calculations of both peak capacity and design capacity flow have been outlined below to explain these discrepancies.

Although, "as received" fuel weights will be used for purposes of waste input measurements, EPA Method 19 Section 12.3.2 indicates that F-factor calculations must be calculated using a dry basis due to the fact that the system includes a wet scrubber. Therefore, a mass balance method is preferred to account for the addition or removal of water mass in the scrubber. Although, the mass balance method is used by Dynamis for system design the dry F-factor approach is also valid if corrections are made to account for the saturation of the flue gas in the scrubber. The key correction is to calculate the dry F-factor volumetric flow rate then calculate the mass flow using dry STP gas density. This mass flow rate is then used to calculate the actual/wet volumetric flow at saturation using the saturated density at the stack exit temperature and pressure. Please see Table 1 for additional clarity to the F-factor approach used by Dynamis.

Table 1: Flow calculations using dry F-Factor

	Peak Flow w/max HV fuel	Off-Peak Flow w/max HV fuel
MSW Used (ton/hr)	23.38	3.50
Tires Used (tons/hr)	0.00	0.77
MSW Heating Value (btu/lb)	7,000.00	7,000.00
Final fuel heating value-btu/lb (MSW+Tire+CNG)	7,100.00	9,980.00
F-Factor SCF/MMBTU (MSW+tire)-*see calcs in table 2*	9,757.50	9,728.21
Excess Air (to maintain combustion temp at 2000F)	120%	149%
F-Factor calculated Flow Rate (dscfm)	118,680.00	28,151.83
Flue gas density at 68F dry (lbm/ft^3)	0.0750	0.0750
Mass Flow (lbm/min)	8,901.00	2,111.39
Flue Gas Temp @ Saturation (F)	125.40	134.50
Flue gas density saturated with H20 @3000ft (lbm/ft^3)	0.0590	0.0540
Peak stack flow rate (acfm)	**150,864.40**	**39,099.77**

Maximum system flow conditions will occur during peak operation if the incoming MSW is very energetic due to very dry conditions and very little non-combustible material. See Table 2 for a breakdown of this type of waste heating value and Table 3 for an ultimate analysis. The facility has the capacity to process 374 tons MSW/daily peak and 28 tons MSW/daily off peak + 6.1 tons tires/daily off peak with MSW having a maximum LHV of 7000 btu/lb. This fuel mix results in combustion conditions that require significant amounts of excess air to maintain proper temperatures. Approximately 120% excess air will be used, opposed to the 50% used in the previous calculations by DEQ. The F-factor for this type of waste is also different from waste more typical of WTE facilities. The F-factor was calculated using the ultimate analysis indicated in Table 3 and EPA Method 19 Section 12.3.2.1. The F-factor calculated here is higher than the value of 9570 dscf/MMBTU suggested in your letter but this is to be expected given the high hydrocarbon content of this potential waste.

Table 2: High Energy Value MSW

Maximum "as received" LHV System can utilize at full capacity	7000	btu/lb
Percentage water in waste	11.0%	
Heat lost to vaporize water in LHV	113.30	btu/lb
High Heating Value (HHV)	7113.30	btu/lb
Maximum System Capacity during peak	374	ton fuel as received
Operation Hours	16	
Hourly Heat Input	327,250,000.00	MMBTU/hr
	Percentage by mass	**Weight (tons)**
Waste Moisture	11%	41.14
Dry Feed		332.86
Non-combustible portion (by weight-glass, metal, ceramic, etc.)	9.0%	29.96
Combustible Portion of Waste		302.90
Combustible Portion Heating Value	8,643.04	BTU/lb

The off peak fuel mix is overall more energetic than the peak fuel due to the addition of tires. About 150% excess air will be required to keep temperatures at optimal levels. The off peak F-factor is slightly lower than peak due to that the factor is the result of both an MSW F-factor and tire F-factor. The tires have a higher carbon content and lower hydrogen content then the MSW so the overall F-factor is decreased slightly. Tables 4 and 5 show the calculations used for the tire F-factor.

Table 3: Combustible MSW Portion-Ultimate Analysis [1]

	C%	H2%	O2%	S%	N2%
Percent of combusted material (by mass)	51.5	6.5	40.18	0.25	1.57
F-Factor Conversion (scf/lb/%)	1.53	3.64	0.46	0.57	0.14
Products of combustion/pound of compound (dscf/lb of waste)	78.795	23.66	18.48	0.1425	0.2198

Btu to MMBTU conversion	1.00E+06
F-Factor (DSCF combustion products/MMBTU)	9,757.50

Table 4: Tire Fuel-Used during Off Peak		
Maximum "as received" LHV System can utilize at full capacity	13,628	btu/lb
Percentage water in waste	5.0%	
Heat lost to vaporize water in LHV	51.50	btu/lb
HHV	13,679.50	btu/lb
Maximum System Capacity during off peak	6.1	ton fuel as received
Operation Hours	8	hr
Hourly Heat Input	20,782,700	MMBTU/hr
	Percentage by mass	**Weight (tons)**
Waste Moisture	5%	0.305
Dry Feed		5.795
Non-combustible portion (metal belts, wire beads, nylon fibers, dirt, etc.)	12%	0.70
Combustible Portion of Waste		5.10
Combustible Portion Heating Value	16,301.44	BTU/lb

Table 5: Combustible Tire portion-Ultimate Analysis [1]

	C%	H2%	O2%	S%	N2%
Percent of combusted material (by mass)	89.29	5.6	2.17	2.7	0.24
F-Factor Conversion (scf/lb/%)	1.53	3.64	0.46	0.57	0.14
Products of combustion/pound of compound (dscf/lb of waste)	136.61	20.38	0.998	1.539	0.034

Btu to MMBTU conversion	1.00E+06
F-Factor (DSCF combustion products/MMBTU)	9,666.15

Additional flow conditions were calculated for fuel streams with heating values more typical of MSW. These conditions resulted in lower system flows and higher modeled ambient impacts due to reduced dispersion. System flows were calculated for MSW typical of Ada County with a LHV of 5800 btu/lb (moisture content of 20% and incombustible content of 13%). See Table 6 for peak and off peak stack flows and Table 8 for MSW F-factor calculations. The F-factor used for tires in off peak is the same as the previous condition. Overall excess air requirements are lower than the max flow case due to lower temperatures during combustion.

Table 6: Flow calculations using dry F-Factor

	Peak Flow w/typical heating value fuel	Off-Peak Flow w/typical heating value fuel
MSW Used (ton/hr)	23.1875	3.9
Tires Used (tons/hr)	0.00	0.77
MSW Heating Value (btu/lb)	5,871	5,871
Final fuel heating value-btu/lb (MSW+Tire+CNG)	5,936	8,867
F-Factor SCF/MMBTU (MSW+tire combined)-*see calcs in table 2*	9,320	9,426
Excess Air (to maintain combustion temp at 2000F)	121%	130%
F-Factor calculated Flow Rate (dscfm)	94,439.50	24,855.65
Flue gas density at 68F dry (lbm/ft^3)	0.0750	0.0750
Mass Flow (lbm/min)	7,082.96	1,864.17
Flue Gas Temp @ Saturation (F)	125.40	135.00
Flue gas density saturated with H20 @3000ft (lbm/ft^3)	0.0590	0.0550
Peak stack flow rate (acfm)	**120,725**	**33,894**

Table 7: Moderate Heating Value MSW		
Typical "as received" LHV fuel	5871	btu/lb
Percentage water in waste	20.0%	
Heat lost to vaporize water in LHV	206.0	btu/lb
HHV	6077.0	btu/lb
Maximum System Capacity during off peak	371	ton fuel as received
Operation Hours	16	hr
Hourly Heat Input	272,267,625	MMBTU/hr
	Percentage by mass	**Weight (tons)**
Waste Moisture	20%	74.2
Dry Feed		296.8
Non-combustible portion (glass, metal, ceramic, dirt, etc.)	9%	26.71
Combustible Portion of Waste		270.09
Combustible Portion Heating Value	8,064.56	BTU/lb

Table 8: Combustible MSW Portion-Ultimate Analysis [1]

	C%	H2%	O2%	S%	N2%
Percent of combusted material (by mass)	49.36	5.29	43.45	0.25	1.65
F-Factor Conversion (scf/lb/%)	1.53	3.64	0.46	0.57	0.14
Products of combustion/pound of compound (dscf/lb of waste)	75.52	19.26	19.99	0.143	0.231

Btu to MMBTU conversion	1.00E+06
F-Factor (DSCF combustion products/MMBTU)	9,320

Dioxin/Furan Emission Calculations

Initial dioxin and furan emissions calculations were based on source test data from the April-May 1993 Entech Model TOS-80 system in Anchorage, Alaska. After this data was made public, members of the general public expressed concern regard de novo synthesis (reformation) – a process by which PCDD/PCDF which was destroyed by the high combustion temperatures in the thermal unit may reform on fly ash as the exhaust gasses pass through the steam generator and are cooled prior to exhaust to the atmosphere. It is safe to say that determining exact dioxin/furan destruction and reformation in a combustion system is a complex area of science requiring significant knowledge of the fuel, gasification/combustion process, flue gas composition and system temperatures. The Dynamis technology to be installed

at the Ada County facility has been fully supported by industry experts as a system with very low dioxin/furan emission. Dr. John Nordin personally evaluated the base technology that Dynamis designs use and stated:

> "Western Research Institute [WRI] believes that this Entech Model TOS-80, as tested lends itself to low dioxin/furan formation. The particulate emissions are low, and flue gas mixing in the secondary combustion chamber allows for excellent destruction of products of incomplete combustion. Dioxin/furan emissions from MSW incinerators have been evaluated by a number of researchers (Hoffman et al. 1990: Acharya et al. 1991; Shaub and Tsang 1983). Hydrogen chloride or chlorine in the flue gas reacted with products of incomplete combustion (PIC's: phenols, chlorobenzene, chlorophenols, polyaromatics), which are absorbed onto fly ash particulates. These PIC's, in turn form dioxin/furans."

The general public has also raised questions regarding variations in the source test data. The data variation is well documented and explained in the source test reports. During operation of the TOS-80 in 1993 dioxin/furan measurements were collected from nine tests with varying waste streams. During test 1 an upset condition (a condition well understood in the emissions monitoring industry to be a momentary rare occurrence) occurred causing elevated dioxin/furan measurements. Reference to this upset condition can be found in Volume I—Text April-May 1993 Entech, Inc., Model TOS-80 Emissions Monitoring in Anchorage, Alaska in the Summary section on page V in the second paragraph. The authors of the report state, "One exception occurred during the early part of burn 1, when the operator's experiment with system capabilities resulted in visible emissions of black, particulate-laden smoke from the stack." Additionally on page VI, the author mentions, "The high dioxin and furan levels were barely distinguishable from the field blank for most burns." A further description of the upset condition is described in the "Organics" section on page 35, "The organic sampling for burn 1 occurred when the series of smoke puffs were observed. This was because forced air was fed to the primary combustion chamber at the same time that the exhaust gas was constricted…The result was an average of 1.51 ng/dscm of dioxins/furans collected, which were weighted heavily toward trichlorinated dibenzo furans and pentachlorinated dibenzofurans or octachlorinated dibenzo furans… For all other burns, total dioxins and furans were very low, and barely distinguishable from the field blank." See the attached charts of dioxin and furan cogeners from these tests for further clarity. These elevated measurements clearly represent outlying data that justify removal from the emissions calculations.

The Entech Model TOS-80 system did not include a heat recovery steam generator (HRSG), and therefore, exhaust from that unit did not go through the cooling process known to cause de novo synthesis. In response to this, Dynamis reviewed various references regarding PCDD/PCDF emission pathways including initial formation as well as de novo synthesis; some of these references are listed in this letter for your convenience. A major complicating factor in the calculation of reformation of

PCDD/PCDF, is that the exact amount of PCDD/PCDF reformation is dependent on many very complex reactions including, but not limited to the presence of chlorinated compounds in the exhaust gas, as well as the concentration of fly ash in the exhaust. Therefore the references included with this letter have been used only as an estimate of possible PCDD/PCDF reformation emissions. The calculated reformation emissions have been added to the source test data to develop a 'total' (formation + reformation) emission factor (see Table 9 for the calculation methodology used). The emissions calculations likely provide an overestimate of the actual Dynamis Ada County facility PCDD/PCDF emissions, however due to the complexity of the chemical reactions involved in the formation and reformation of PCDD/PCDF, source tests conducted at the Dynamis Ada County facility will provide the most accurate measure (and demonstration of compliance with NSPS limits) of PCDD/PCDF emissions from the facility.

Table 9: Estimation of De Novo Synthesis through Ada County WTE Heat Recovery Steam Generator (HRSG)

	De Novo Synthesis (Reformation)-w/150 ug/m^3 chlorophenol precursor**	Source Test Emission Factor (emission prior to HRSG)	Total Emission Factor (TM-17 + De Novo Synthesis)
Typical Reformation Rate (ng/g/min)	3300		
PM2.5 emission from secondary chamber (lb/hr)	6.5		
PM2.5 emission from secondary chamber (g/min)	49.14		
HRSG length between 500-200C* (ft)	48		
Minimum flue gas velocity through HRSG (ft/sec)	37		
Time in Reformation temp. Region (min)	0.0167		
Min. Flow Rate through Reformation Region (m^3/min)	5.47E+03		
Estimated TM-17 reformed concentration (ng/m^3)	4.95E-01	1.56E+00	**2.06E+00**
Conversion ratio (TM-17:TEQ from above table)	1.06E+02		
Toxicity Equivalent (TEQ)-ng/m3	4.68E-03	1.48E-02	**1.94E-02**

*Data shows the most critical temperature range for De Novo Synthesis to occur is 250-500C [2]
**The reformation rate used is from report summarizing experimental tests on dioxin De Novo Synthesis [3]. Source tests show chlorophenol concentrations as "non-detect" so this estimation is considered 'worst-case.'

In summary, the F-factor method of estimating system flows is in close agreement with the mass balance approach used by Dynamis as long as excess air requirements and added scrubber water are correctly accounted for. The F-factors calculated for the various heating value wastes are reasonably close to the F-factor used in AP-42. This indicates the waste ultimate analysis used by Dynamis and supported by industry publications is similar to the ultimate analysis used to generate the AP-42 F-factor of 9570 DSCF/MMBTU. References to the cause of the upset condition and an explanation of elevated dioxin/furan measurements from the 1993 test 1 of the TOS-80 system are included. These elevated measurements clearly represent outlying data that justify removal from the emissions calculations. Estimation of dioxin reformation through the system HRSG has been calculated to account for the difference between the pilot plant and the Ada County facility. The system shows compliance with the NSPS limit of 13 ng/dscm and source tests will occur to verify this compliance. Please contact me with any further questions or clarifications regarding these issues.

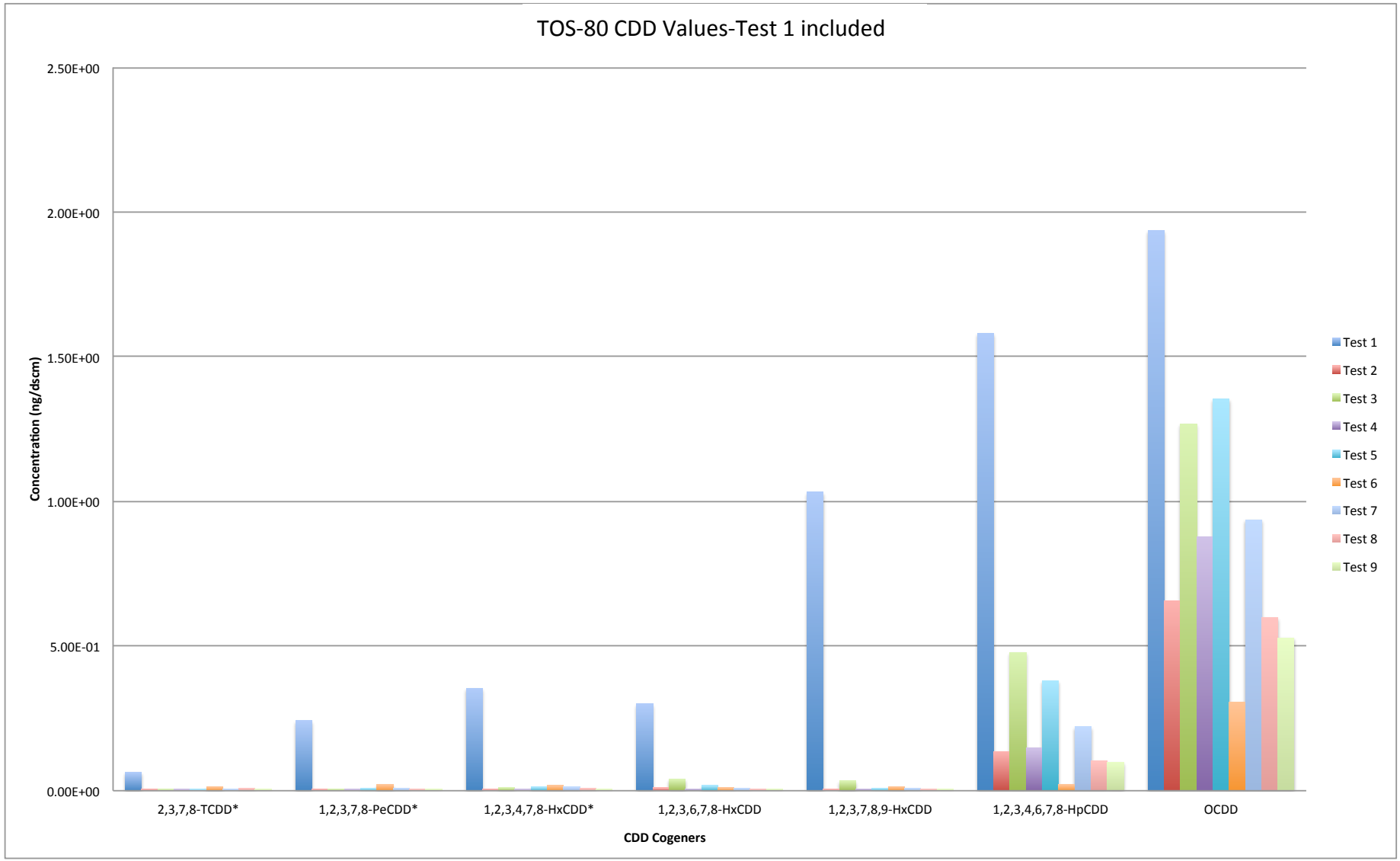
Dynamis Energy, LLC

Christopher Durand, P.E.
Senior Mechanical Engineer

cc: Shannon Manoulian, JBR
C. Lloyd Mahaffey, CEO
Wade Thomas, SVP, Legal and Finance
Michael Bogert, Parson Behle

References:

1. Handbook of solid waste management: George Tchobanoglous, co-editor; Frank Kreith, co-editor.-2nd ed. (2002) 13.60
2. U.S. Environmental Protection Agency. (2006) "An inventory of sources and environmental releases of dioxin-like compounds in the United States for the years 1987, 1995, and 2000. National Center for Environmental Assessment, Washington, DC; EPA
3. Dioxin characterization, formation and minimization during municipal solid waste (MSW) incineration: review; Gordon McKay; Department of Chemical Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; Chemical Engineering Journal 86 (2002) 343-368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Test 5
Test 6
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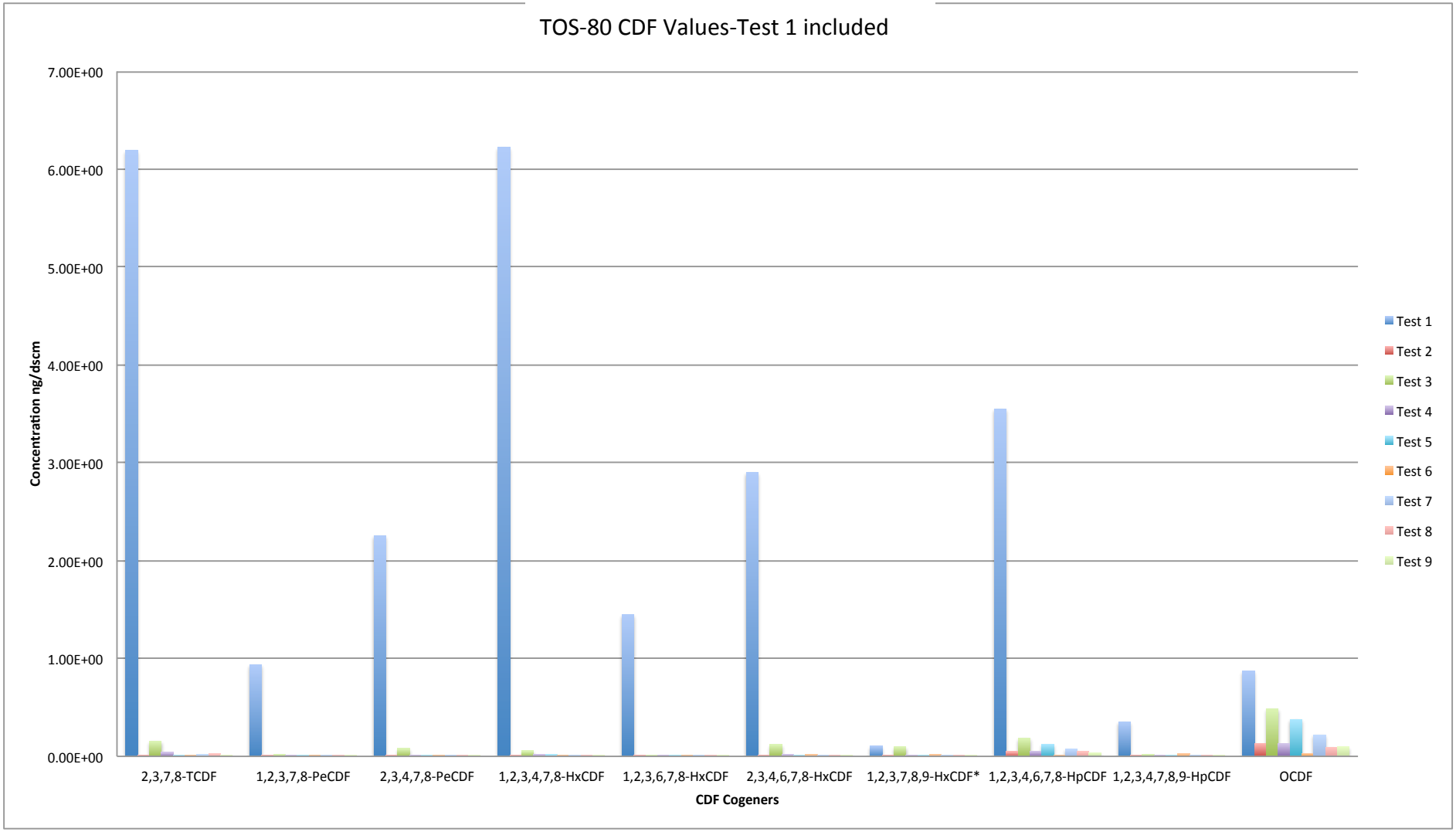
Test 8
Test 9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Concentration ng/dscm
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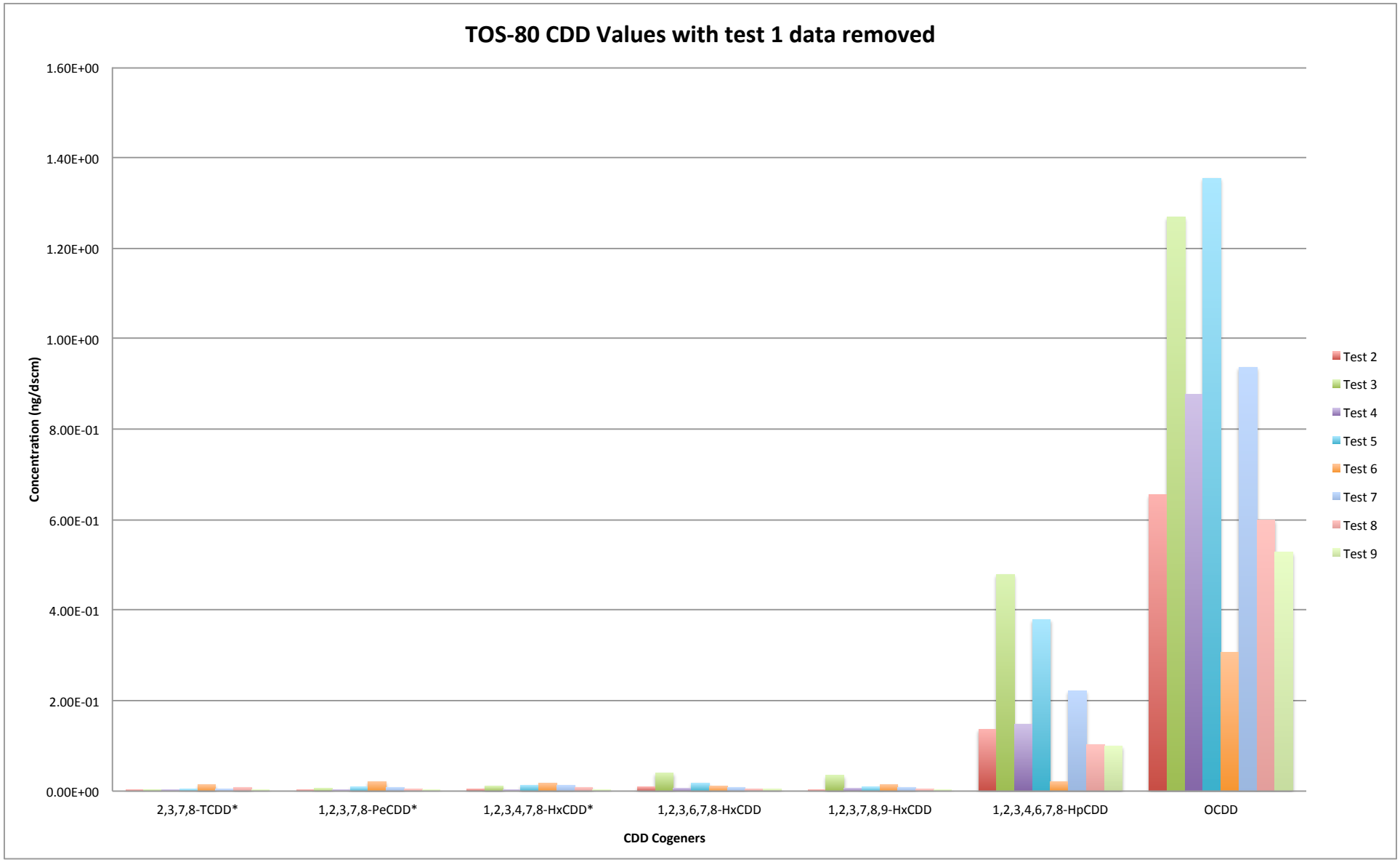
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Concentration (ng/dscm)
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1,2,3,7,8-PeCDD*
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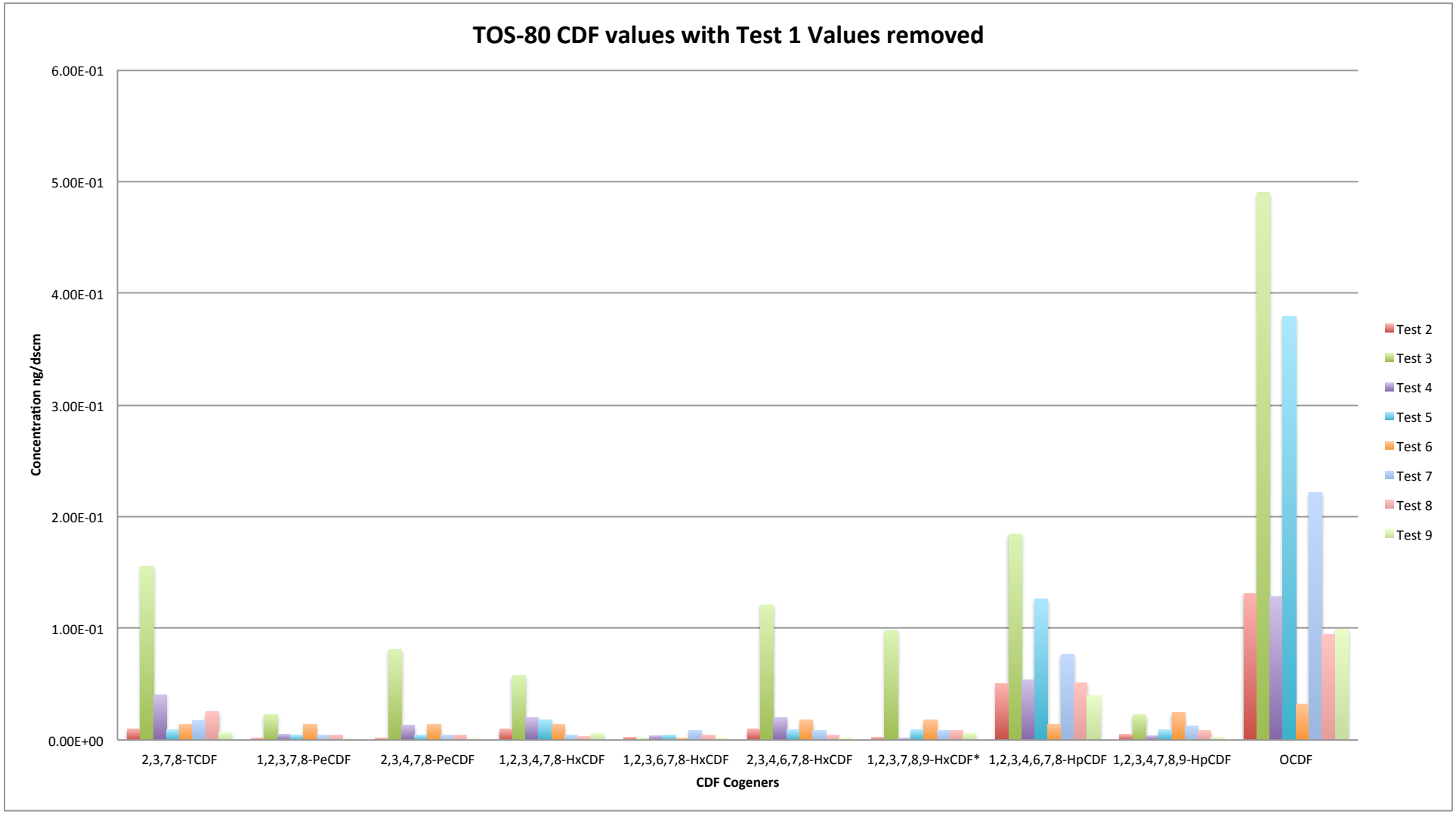
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1,2,3,7,8-PeCDF
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OCDF
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Test 2
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