



Calculation Cover Sheet

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RPP-WTP PDC

Sheet i

RIVER PROTECTION PROJECT-WASTE TREATMENT PLANT		JOB NO.: 24590	
CALC NO. 24590-BOF-M4C-DEP-00001	GROUP Process Eng.	FACILITY BOF	
SUBJECT DFLAW Effluent Management Facility Air Emissions Estimate			
CALCULATION STATUS <input type="checkbox"/> PRELIMINARY <input checked="" type="checkbox"/> COMMITTED <input type="checkbox"/> CONFIRMED <input type="checkbox"/> SUPERSEDED BY: _____ <input type="checkbox"/> CANCELLED			

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Excel 2003
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 Mathcad 11.2a
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PROGRAM NAME	VERSION NO	UIF		COMPUTER PLATFORM		
		NO	REV	MICROPROCESSOR	OPERATING SYSTEM	JO#

RECORD OF REVISIONS							
NO.	REASON FOR REVISION	TOTAL NO. OF SHEETS	LAST SHEET NO.	ORIGINATOR	CHECKED	APPROVED/ ACCEPTED	DATE
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Affected areas are identified by revision bars in the right margin.

For this revision, it has been confirmed that the inputs and assumptions are current and reflect the current issued state of design.

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SHEET NO.: 1

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Acronyms and Abbreviations

ACV	- Active Confinement Ventilation
APQ	- Annual possession quantity
BOF	- Balance of Facilities
CAS	- Chemical Abstracts Service
CNP	- Cesium Nitric Acid Recovery Process system
COPC	- Constituents of Potential Concern
CRV	- Concentrate Receipt Vessel
DEP	- DFLAW EMF Process system
DF	- Decontamination factor
DFLAW	- Direct Feed Low Activity Waste
DVP	- DFLAW EMF Process Vessel Ventilation system
EMF	- Effluent Management Facility
ETF	- Effluent Treatment Facility
HEPA	- High Efficiency Particulate Air
HLW	- High Level Waste Facility
ICD	- Interface Control Document
LAW	- Low-Activity Waste Facility
LAWPS	- LAW Pretreatment System
LERF	- Liquid Effluent Retention Facility
LFP	- LAW Melter Feed Process system
LVP	- LAW Secondary Offgas/Vessel Vent Process system
MDR	- Mass distribution ratio
ORNL	- Oak Ridge National Laboratory
PFD	- Process flow diagram
PIC	- Product of incomplete combustion
PTF	- Pretreatment Facility
R&T	- Research and Technology
RAIS	- Risk Assessment Information System
RLD	- Radioactive Liquid Waste Disposal system
SBS	- Submerged bed scrubber
TAP	- Toxic air pollutant
TOC	- Total organic carbon
TRU	- Transuranic
VSL	- Vitreous State Laboratory of the Catholic University of America
WAC	- Washington Administrative Code
WESP	- Wet electrostatic precipitator
WTP	- Hanford Tank Waste Treatment and Immobilization Plant

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1 Objective

The objective of this calculation is to provide an air emissions estimate for the Direct Feed Low Activity Waste (DFLAW) Effluent Management Facility (EMF) at the Hanford Tank Waste Treatment and Immobilization Plant (WTP). This calculation estimates emissions for organic, inorganic, and radionuclide constituents of potential concern (COPCs) from the DFLAW EMF Process Vessel Ventilation system (DVP). Radionuclide COPC emissions from the Active Confinement Ventilation (ACV) exhaust system are also estimated. The annual possession quantities (APQs) for radionuclide COPCs in the DFLAW EMF Process (DEP) system are also estimated. Results are given in g/sec for organic and inorganic COPCs and Ci/yr for radionuclide COPCs.

2 Inputs

- 2.1 Specific activities of radionuclide COPCs in Ci/g are shown in Attachment B. The specific activities are found in the Oak Ridge National Laboratory (ORNL) *Risk Assessment Information System* (RAIS) (Ref. 10.1).
- 2.2 Table 2-1 shows the treated LAW waste acceptance limits for radionuclides established in *ICD-30 – Interface Control Document for Direct LAW Feed* (Ref. 9.3, Table 5).

Table 2-1 – ICD-30 Acceptance Limits for Radionuclide Concentrations

	ICD-30 Limits
	Concentration
¹³⁷ Cs	3.18E-05 Ci/mol sodium
¹⁵⁴ Eu	1.8E-05 Ci/L
⁶⁰ Co	1.1E-06 Ci/L
⁹⁰ Sr	1.19E-03 Ci/mol sodium
⁹⁹ Tc	4.8E-04 Ci/L
²³⁹ Pu	3.0E-05 Ci/L
²³³ U	1.6E-07 Ci/L
²³⁵ U	1.7E-09 Ci/L
TRU	1.30E-05 Ci/mol sodium
U fissile to U total ¹	0.96 wt%

Note 1: Total uranium is the sum of masses of ²³³U, ²³⁵U, and ²³⁸U (Ref. 9.3, Table 5, Note 16). Fissile uranium is calculated per Equation 6 in Section 5.1.1.1.3 of this calculation.

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- 2.3 The median entrainment factor for the free-fall spill of an aqueous solution (density ~ 1.0 g/cm³) is $4E-5$ g entrained material / g air (Ref. 10.2, Page 3-4).
- 2.4 The volume of the feed transfer line flush from Tank Farms LAW Pretreatment System (LAWPS) facility to the DFLAW EMF Process system (DEP) low point drain vessel (DEP-VSL-00001) is determined by the next planned transfer of feed (Ref. 9.3, Section 2.6.2):
- If the next transfer of feed is expected in less than 72 hours, the Tank Operations Contractor will flush the transfer pipeline with a volume of water that is not more than the transfer pipeline volume (1500 gallons [5.68 m³])
- If the next transfer of feed is expected to be more than 72 hours later, then the Tank Operations Contractor will flush the transfer pipeline with a volume of water that is at least 1.5 times the transfer pipeline volume (2200 gallons [8.33 m³])
- 2.5 The molecular weight of sodium (Na) is 22.9898 g/mol (Ref. 10.3, inside of back cover).
- 2.6 The molecular weight of carbon (C) is 12.01115 g/mol (Ref. 10.3, inside of back cover).
- 2.7 The molecular weight of water (H₂O) is 18.02 g/mol (Ref. 10.3, inside of back cover).
- 2.8 The average molecular weight of air is 28.97 g/mol (Ref. 10.3, Page 21-8)
- 2.9 The molecular weight of ammonia (NH₃) is 17.031 g/mol (Ref. 10.3, inside of back cover).
- 2.10 The molecular weight of mercury (Hg) is 200.59 g/mol (Ref. 10.3, inside of back cover).
- 2.11 Transuranic (TRU) radionuclides are defined as alpha-emitting radionuclides with an atomic number greater than 92 with half-life greater than 20 years (Ref. 10.4, Page C-119 Note 2).
- 2.12 The nominal diameter of the WTP portion of the feed transfer line from LAWPS to Low-Activity Waste Facility (LAW) is 3 inch Schedule 40 per ICD-30 (Ref. 9.3, Table 2). This corresponds to an inside diameter of 3.068 inches (Ref. 10.5, Page B-13).
- 2.13 De minimis values for the emissions of toxic air pollutants (TAPs) are provided in Washington Administrative Code (WAC) Section 173-460-150 (Ref. 10.7).
- 2.14 The density of the Radioactive Liquid Waste Disposal system stream (RLD21) is 62.6 lb/ft³, or 1002.8 g/L (Ref. 9.22, Table B-25).
- 2.15 The available batch volume of the Caustic Collection Tank (LVP-TK-00001) is 4,336 gallons (Ref. 9.26, Section 7.5.14 and Section 8).
- 2.16 The transfer frequency for LVP-TK-00001 is once every 10.7 hours (Ref. 9.26, Section 8).
- 2.17 The density of the LAW Secondary Offgas/Vessel Vent Process system stream (LVP21) is 65.8 lb/ft³, or 1054.0 g/L (Ref. 9.22, Table B-23).

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- 2.18 The Henry's Law constant for ammonia is $3.45E-6 \text{ atm}\cdot\text{m}^3/\text{mol}$ (Ref. 10.11).
- 2.19 The ICD-30 acceptance limit for mercury is $1.4E-5 \text{ mol Hg/mol Na}$ (Ref. 9.3, Table 5).
- 2.20 The release fraction (entrainment factor) for liquids or particulate solids provided in WAC 246-247-030 is $1E-3 \text{ g entrained material / g air}$ (Ref. 10.8, Section 21(a)).

3 Background

The list of COPCs for air permitting at WTP is compiled in 24590-WTP-RPT-ENV-10-001 – *Constituents of Potential Concern for the WTP Air and Dangerous Waste Permits* (Ref. 9.1). Table 2-1 in Ref. 9.1 shows the entire list of 409 compounds considered WTP COPCs, along with the source document justifying each compound's addition to the list. The following categorization summarizes the number and type of the COPCs (Ref. 9.1, Page 25).

- 309 organic COPCs, including:
 - 138 feed compounds
 - 171 stack emissions compounds
- 54 inorganic COPCs, including:
 - 43 feed compounds (11 with radioactive forms)
 - 11 stack emissions compounds
- 46 radionuclide COPCs (all feed constituents)

The stack emissions compounds are products of incomplete combustion (PICs) that are generated from the destruction of organics in the melter and not present in the feed stream.

The complete list of WTP COPCs evaluated for air emissions is shown in Attachment A.

The DFLAW EMF is being added to support DFLAW operations by handling secondary waste streams associated with the melter off-gas (i.e., submerged bed scrubber (SBS) condensate, wet electrostatic precipitator (WESP) drain, and caustic scrubber solution) and line flushes/drains. An evaporator is used to concentrate the SBS condensate/plant wash effluent and recycle the effluent concentrate to the front end of LAW (LCP-VSL-00001/2) to be incorporated into the glass during the vitrification process. The EMF evaporator overheads stream is combined with the LAW Caustic Scrubber effluent stream and then sent to the Liquid Effluent Retention Facility (LERF)/Effluent Treatment Facility (ETF) for final treatment prior to discharge to the environment. The EMF evaporator and other process components are part of a new system, the DEP system, which will be part of the Balance of Facilities (BOF).

Process flow diagrams (PFDs) for the DEP system are shown in References 9.5, 9.6, 9.7, and 9.8. The main process vessels in the DEP system are the low point drain vessel (DEP-VSL-00001), evaporator feed vessel (DEP-VSL-00002), evaporator concentrate vessels (DEP-VSL-00003A/B/C), overhead sampling vessels (DEP-VSL-00004A/B), and process condensate lag storage vessels (DEP-VSL-00005A/B), along with the DEP evaporator system, represented by the evaporator separator vessel (DEP-EVAP-00001), primary/inter/after-condensers (DEP-COND-00001/2/3), and reboiler (DEP-RBLR-00001).

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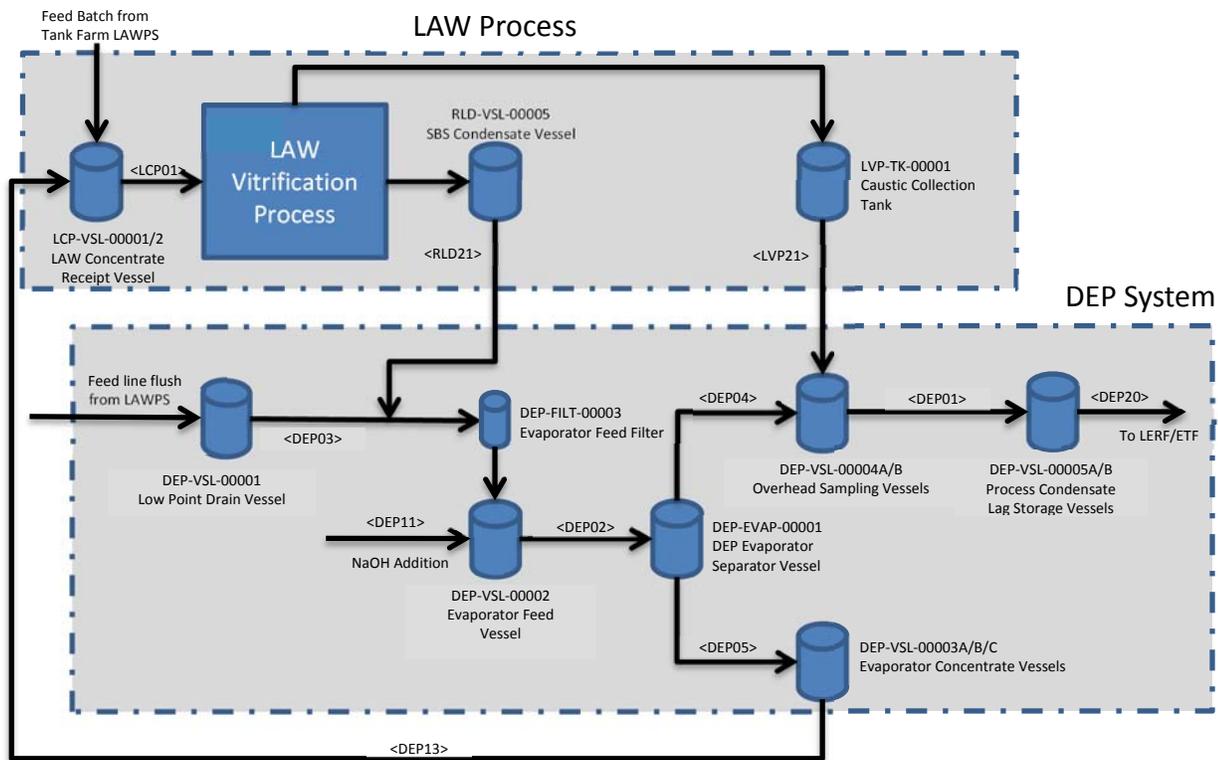
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The DVP system is comprised of two main parts, air supply and exhaust, and its purpose is to maintain hydrogen below dangerous levels in the vessel headspace. The inlet air, or purge air, is supplied by a passive system. For the DEP vessels in the LAW effluent process building, a purge air in-bleed is suitable for meeting the very low required flowrates. The vessel vent is the exhaust or discharge portion of the DVP system that provides the suction pressure on the vessel headspace, drawing in the purged air, and evacuates the hydrogen. The discharge air is sent through a preheater, two-stage high efficiency particulate air (HEPA) filters, and finally through an exhaust fan to discharge the air out of the EMF stack (Ref. 9.7).

Figure 3-1 and Figure 3-2 show a simplified flow diagram for the DEP system and DVP exhaust system, respectively

Figure 3-1 - DEP System - Simplified Flow Diagram



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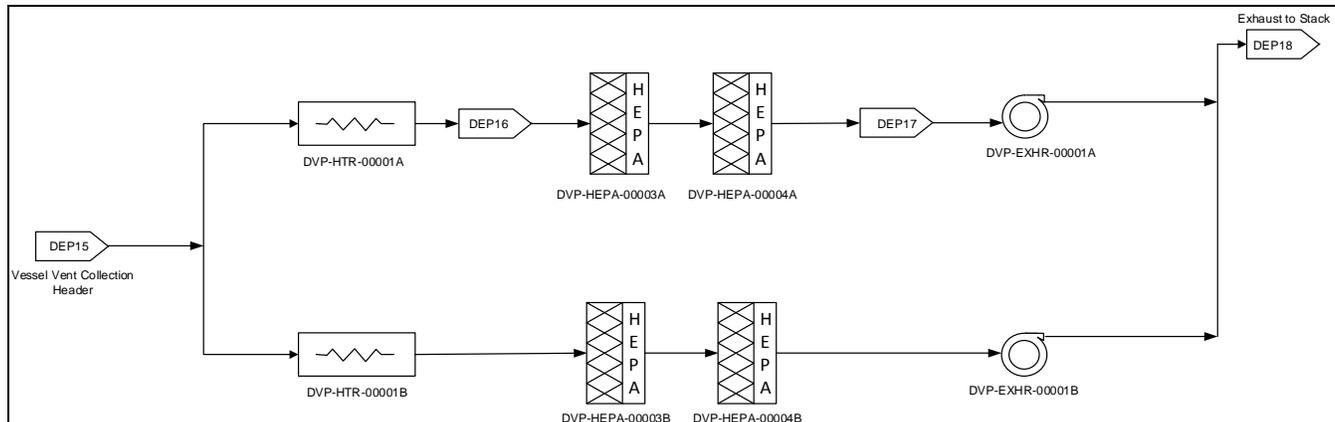
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Figure 3-2 - DVP Exhaust System - Simplified Flow Diagram



4 Applicable Codes and Standards

- 4.1 Washington Administrative Code (WAC) 173-460-150 - *Table of ASIL, SQER and de minimis emission values.*
- 4.2 Washington Administrative Code (WAC) 246-247-030 – *Definitions.*

5 Methodology

The methodology for estimating the emissions from the EMF is divided into three main sections: radionuclide COPCs, organic COPCs, and inorganic COPCs. The general approach within each section is to evaluate the COPCs based on their expected emission phase (i.e. vapor or particulate).

The main governing assumption for particulate emissions is that the mass fractions of COPCs emitted through entrainment are assumed to remain constant throughout the DEP system at the maximum feed vector batch mass fraction. For PICs, which are not present in the feed vector, the mass fractions of PIC COPCs emitted through entrainment are assumed to remain constant throughout the DEP system at the mass fraction received in the DEP system from Stream RLD21 (Assumption 6.1.1).

Additional key assumptions for entrainment are the applicability of the entrainment factors used for the DEP vessels (Assumption 6.2.3) and the DEP evaporator (Assumption 6.2.30).

The main governing assumption for vapor emissions is that the entire volatile fraction of a COPC received in the DEP system will be emitted in the vapor phase as it is processed through the DEP system (Assumptions 6.2.4, 6.2.16, and 6.2.23). Any special cases not following this assumption will be specifically mentioned and an alternative estimation method will be described.

The calculation spreadsheets and data files associated with 24590-WTP-RPT-ENV-16-001 - *Feed Vector Development In Support Of WTP Environmental Risk Assessment Activities* (Ref. 9.2) are accessible through 24590-RMCD-04893. The values associated with the DFLAW Bounding Feed Vector and Tank Farm Average ratios, that are used throughout this calculation, were accessed from Excel spreadsheets

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“*Bounding_DFLAW-batches-to-wtp.csv*” and “*COPC and non-COPC Organic Tank Farm Ratios.xlsx*” respectively.

5.1 Radionuclide COPC Emissions

Attachment A, Table A-1 shows the 46 radionuclides tracked as COPCs at WTP.

5.1.1 COPC Maximum Batch Activities

The maximum batch activity for the radionuclide COPCs is determined using the Tank Farms Average ratios (mCi COPC / g Na) and the DFLAW Bounding Feed Vector maximum sodium batch. The Tank Farms Average ratios are provided in Ref. 9.2. These Tank Farms Average ratios are assumed to be applicable to this analysis (Assumption 6.2.1). The DFLAW Bounding Feed Vector is provided in Ref. 9.2 and used in this calculation (Assumption 6.2.2). The values for the amount of sodium (in kmol) in each batch during the DFLAW campaign are extracted from the DFLAW Bounding Feed Vector and then the average, minimum, and maximum values are calculated.

The Tank Farms Average ratios are converted to the maximum batch activity of each radionuclide as follows:

$$A_i = r_i * n_{Na,max} * MW_{Na} * 1000 \frac{mol}{kmol} * \frac{1 Ci}{1000 mCi} \quad \text{Equation 1}$$

Where:

A_i = Maximum feed vector batch activity of COPC i , in Ci

r_i = Tank Farms Average ratio of COPC i , in mCi COPC / g Na (Ref. 9.2)

$n_{Na,max}$ = Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmols (Attachment G)

MW_{Na} = Molecular weight of sodium, in g/mol (Input 2.5)

5.1.1.1 ICD-30 Acceptance Limits

The maximum batch activities of radionuclides that have acceptance limits established in ICD-30, as shown in Input 2.2, are compared to their ICD-30 acceptance limit. If a limit is exceeded, the maximum batch activity is adjusted to equal the ICD-30 acceptance limit, since the Tank Operations Contractor must demonstrate compliance with the criteria in Table 5 of ICD-30 prior to WTP agreeing to receive a Treated LAW feed campaign from LAWPS (Ref. 9.3, Section 2.3).

5.1.1.1.1 Convert ICD-30 Acceptance Limits to Activities

All of the ICD-30 limits shown in Table 2-1 (except U fissile to U total) are converted to Curies.

Acceptance limits in units of Ci/L are multiplied by the maximum feed batch volume from the Bounding DFLAW feed vector to calculate the activity of a radionuclide at the ICD-30 limit. The batch volumes of

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each batch during DFLAW operation are extracted from the feed vector (Ref. 9.2) and then the average, minimum, and maximum values are calculated (Attachment G).

For ICD-30 acceptance limits given in Ci/L:

$$A_{i,limit} = c_{i,limit} * V_{max} * \frac{3.785 L}{1 gal} \tag{Equation 2}$$

Where:

- $A_{i,limit}$ = Activity of COPC *i* at ICD-30 limit, in Ci
- $c_{i,limit}$ = Concentration of COPC *i* at ICD-30 limit, in Ci/L (Input 2.2)
- V_{max} = Maximum feed batch volume, in gallons (Ref. 9.2)

Acceptance limits in units of Ci/mol Na are multiplied by the maximum batch amount of sodium, $n_{Na,max}$, to calculate the activity of a radionuclide at the ICD-30 limit.

For ICD-30 acceptance limits given in Ci/mol Na:

$$A_{i,limit} = c_{i,limit} * n_{Na,max} * 1000 \frac{mol}{kmol} \tag{Equation 3}$$

Where:

- $A_{i,limit}$ = Activity of COPC *i* at ICD-30 limit, in Ci
- $c_{i,limit}$ = Concentration of COPC *i* at ICD-30 limit, in Ci/mol Na (Input 2.2)
- $n_{Na,max}$ = Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmols (Ref. 9.2)

Note that there is an ICD-30 limit for total TRU radionuclides. This limit for total TRU needs to be broken out into individual limits for each of the TRU radionuclides. The TRU radionuclides are listed in Table 5-1. This list represents the radionuclide COPCs that meet the TRU criteria in Input 2.11 using radionuclide properties extracted from Ref. 10.6 as shown in Attachment D.

Table 5-1 – TRU Radionuclides

COPC	Atomic Number >92	Half-life > 20 years	Alpha Emitter?
²³⁷ Np	93 (Yes)	2.144E6 (Yes)	Yes
²³⁸ Pu	94 (Yes)	87.7 (Yes)	Yes
²³⁹ Pu	94 (Yes)	24110 (Yes)	Yes
²⁴⁰ Pu	94 (Yes)	6561 (Yes)	Yes
²⁴¹ Am	95 (Yes)	432.6 (Yes)	Yes
²⁴² Pu	94 (Yes)	3.75E5 (Yes)	Yes
²⁴³ Am	95 (Yes)	7370 (Yes)	Yes
²⁴³ Cm	96 (Yes)	29.1 (Yes)	Yes
²⁴⁴ Cm	96 (Yes)	18.1 (NO)	Yes

NOTE: ²⁴⁴Cm has a half-life less than 20 years, however it is included as a TRU radionuclide due to it meeting the other criteria.

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First, the fractional contribution of each TRU radionuclide in the maximum feed vector batch is calculated. Then, the total TRU limit is multiplied by the fractional contribution of each TRU radionuclide to get the individual limits.

$$y_i = \frac{A_i}{A_{TRU}} \quad \text{Equation 4}$$

Where:

$$\begin{aligned} y_i &= \text{Fractional contribution of TRU radionuclide } i \text{ to total TRU in the maximum feed vector batch} \\ A_i &= \text{Maximum feed vector batch activity of TRU radionuclide } i, \text{ in Ci (Equation 1)} \\ A_{TRU} &= A_{237Np} + A_{238Pu} + A_{239Pu} + A_{240Pu} + A_{241Am} + A_{242Pu} + A_{243Am} + A_{243Cm} + A_{244Cm} \end{aligned}$$

$$A_{i,limit} = y_i * A_{TRU,limit} \quad \text{Equation 5}$$

Where:

$$\begin{aligned} A_{i,limit} &= \text{Activity of individual TRU radionuclide } i \text{ at ICD-30 limit, in Ci} \\ A_{TRU,limit} &= \text{Activity of total TRU at ICD-30 limit, in Ci (Equation 3)} \end{aligned}$$

5.1.1.1.2 Compare Maximum Feed Vector Batch Activities to ICD-30 Limit Activities

The maximum batch activities of radionuclides that have acceptance limits established in ICD-30, as shown in Input 2.2, are compared to the activities at the ICD-30 limit calculated using Equation 2, Equation 3, or Equation 5. If the maximum batch activity exceeds the ICD-30 limit activity, then the maximum batch activity is adjusted to equal the ICD-30 limit activity.

5.1.1.1.3 U Fissile to U Total Limit

The Uranium fissile to Uranium total limit is shown in Table 2-1 as a weight percent. Total uranium is the sum of ^{233}U , ^{235}U , and ^{238}U (Ref. 9.3, Table 5). Fissile uranium is calculated per the equation provided in Ref. 9.30, Section 4.1.2. The weight percent of Uranium fissile to Uranium total in the maximum feed batch is calculated using the following equation.

$$m_{U,fissile} = 1.25 * m_{233U} + m_{235U} \quad \text{Equation 6}$$

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$$X_{U \text{ fissile to } U \text{ total}} = \frac{m_{U, \text{fissile}}}{m_{233U} + m_{235U} + m_{238U}} * 100 \quad \text{Equation 7}$$

Where:

- $X_{U \text{ fissile to } U \text{ total}}$ = Weight percent of Uranium fissile to Uranium total
- $m_{U, \text{fissile}}$ = Mass of fissile Uranium, in g
- m_i = Maximum feed vector batch mass of COPC i , in g (Equation 8)

If $X_{U \text{ fissile to } U \text{ total}}$ exceeds the ICD-30 limit for U fissile to U total, then the masses will be adjusted to equal the ICD-30 limit.

5.1.2 COPC Maximum Batch Mass Fractions and Concentrations

The mass of each COPC in the maximum feed vector batch is calculated using the following equation:

$$m_i = \frac{A_i}{SA_i} \quad \text{Equation 8}$$

Where:

- m_i = Maximum feed vector batch mass of COPC i , in g
- A_i = Maximum feed vector batch activity of COPC i , in Ci (Equation 1)
- SA_i = Specific Activity of COPC i , in Ci/g (Input 2.1, Attachment B)

The average feed vector batch total mass is calculated using the average batch volume and density. Average values are used in Equation 9 through Equation 11 for conservatism (Assumption 6.1.34). The values for total volume (in gallons) and density (in g/cc) in each batch during the DFLAW operation are extracted from the DFLAW Bounding Feed Vector (Ref. 9.2) and then the average, minimum, and maximum values are calculated (Attachment G).

The average feed vector batch total mass is calculated as follows:

$$m_{\text{batch, avg}} = V_{\text{batch, avg}} * \rho_{\text{batch, avg}} * 3.785 \frac{L}{\text{gal}} * 1000 \frac{\text{cc}}{L} \quad \text{Equation 9}$$

Where:

- $m_{\text{batch, avg}}$ = Average total feed vector batch mass, in g
- $V_{\text{batch, avg}}$ = Average total feed vector batch volume, in gal (Attachment G)
- $\rho_{\text{batch, avg}}$ = Average total feed vector batch density, in g/cc (Attachment G)

A conservative value for the mass fraction of each radionuclide COPC is then calculated by dividing the maximum batch mass of each COPC by the average total batch mass.

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$$x_i = \frac{m_i}{m_{batch,avg}} \quad \text{Equation 10}$$

Where:

- x_i = Maximum feed vector batch mass fraction of COPC i
 $m_{batch,avg}$ = Average total feed vector batch mass, in g (Equation 9)

A conservative value for the concentration of each radionuclide COPC is calculated by dividing the maximum batch mass of each COPC by the average total batch volume.

$$c_i = \frac{m_i}{V_{batch,avg}} * \frac{gal}{3.785 \text{ liters}} \quad \text{Equation 11}$$

Where:

- c_i = Maximum feed vector batch concentration of COPC i , in g/L
 $V_{batch,avg}$ = Average total feed vector batch volume, in gal (Attachment G)

5.1.3 Radionuclide COPC Emissions Due to Entrainment of Particles/Aerosols

CCN 129507 (Ref. 9.4) assigns vapor phase partitioning coefficient values, F_v , to all WTP COPCs. F_v is a unitless parameter defined as the fraction of a COPC that is in the vapor phase in an offgas stream. All radionuclide COPCs, except for Carbon-14 (^{14}C), Tritium (^3H), and Iodine-129 (^{129}I), are metals and nonvolatile, and are assigned a vapor phase partitioning coefficient, F_v , of 0 and assumed to exist entirely as particles in an offgas stream (Assumption 6.2.9). Particles in an offgas stream are abated by HEPA filtration (Assumption 6.2.10).

^{129}I is also treated as a particle/aerosol for emissions estimation (Assumption 6.2.8).

Emissions of radionuclide COPCs with an F_v of 0 are estimated using offgas entrainment factors. For the entrainment of radionuclides from DEP vessels, an entrainment factor of 4E-5 g entrained material / g air is used based on the median entrainment factor for a free-fall spill of an aqueous solution (Input 2.3). As a conservative and simplifying assumption for this calculation, this entrainment factor is applied to all vessels in the DEP system, except for the evaporator (Assumption 6.2.3). For the entrainment of radionuclides from the DEP evaporator, an entrainment factor of 1E-3 g entrained material / g air is used based on the release fraction prescribed in the WAC 246-247-030 (21)(a)(ii) for liquids and particulate solids (Input 2.20). This entrainment factor is applied to the DEP evaporator per Assumption 6.2.30.

The total mass flow rate of entrained material in the DVP system is calculated as follows:

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$$\bar{m}_{tot,entrained} = (\bar{m}_{ves,vent} * EF_{ves} + \bar{m}_{evap,vent} * EF_{evap}) * 453.5924 \frac{g}{lb} * \frac{1 hr}{60 min} \quad \text{Equation 12}$$

Where:

- $\bar{m}_{tot,entrained}$ = Total mass flowrate of entrained material, in g/min
- $\bar{m}_{ves,vent}$ = Total mass flowrate of the DVP system except for the evaporator, in lb/hr (Assumption 6.1.4)
- EF_{ves} = Entrainment factor for DEP vessels, in g entrained material / g air (Input 2.3)
- $\bar{m}_{evap,vent}$ = Mass flowrate of the evaporator vent stream, in lb/hr (Assumption 6.1.4)
- EF_{evap} = Entrainment factor for DEP evaporator, in g entrained material / g air (Input 2.20)

The mass fraction of each radionuclide COPC in each DEP vessel is assumed to be equal to the value for x_i calculated using Equation 10 (Assumption 6.1.1). With the COPC mass fractions assumed to be constant at the maximum value throughout the DEP system, the bounding value for COPC entrainment is calculated as follows:

$$\bar{m}_{i,entrained} = \bar{m}_{tot,entrained} * x_i \quad \text{Equation 13}$$

Where:

- $\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC i , in g/min
- $\bar{m}_{tot,entrained}$ = Total mass flowrate of entrained material, in g/min (Equation 12)
- x_i = Maximum feed vector batch mass fraction of COPC i (Equation 10)

The entrained mass flow rate is then converted to unabated activity emitted per year using the specific activity.

$$\bar{A}_{i,unabated} = \bar{m}_{i,entrained} * SA_i * 525,600 \frac{min}{year} \quad \text{Equation 14}$$

Where:

- $\bar{A}_{i,unabated}$ = Unabated activity of COPC i emitted per year, in Ci/year
- $\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC i , in g/min (Equation 13)
- SA_i = Specific Activity of COPC i , in Ci/g (Input 2.1, Attachment B)

The DEP vessel ventilation system includes a two-stage HEPA filtration system for removal of particulate prior to release from the EMF stack (Ref. 9.7). The decontamination factors (DFs) of the HEPA filters are given in Assumption 6.2.10. Using the HEPA filter DFs, the abated emissions of radionuclide COPC particles are calculated.

$$\bar{A}_{i,abated} = \frac{\bar{A}_{i,unabated}}{DF_{HEPA,primary} * DF_{HEPA,secondary}} \quad \text{Equation 15}$$

Where:

- $\bar{A}_{i,abated}$ = Abated activity of COPC i emitted per year, in Ci/year
- $DF_{HEPA,primary}$ = Decontamination factor of primary HEPA filter (Assumption 6.2.10)
- $DF_{HEPA,secondary}$ = Decontamination factor of secondary HEPA filter (Assumption 6.2.10)

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5.1.4 Vapor Phase Radionuclide COPCs

^{14}C is assumed to exist as $^{14}\text{CO}_2$ and emitted entirely in the vapor phase of an offgas stream (Assumption 6.2.6).

^3H is assumed to exist as tritiated water ($^3\text{H}_2\text{O}$) and emitted entirely in the vapor phase of an offgas stream (Assumption 6.2.7).

5.1.4.1 Sources of Vapor Phase Radionuclide COPCs

While the concentrations of particle phase radionuclides were assumed to be at the maximum feed vector batch mass fraction throughout the DEP system (Assumption 6.1.1), a different approach is warranted for the vapor phase radionuclides.

^{14}C and ^3H are not likely to reach their maximum feed vector batch mass fractions in the DEP system. Maximum feed vector batch mass fractions are only likely to be reached in the evaporator concentrate and, since volatile radionuclides will mostly partition to the evaporator overhead, ^{14}C and ^3H will not be concentrated in the evaporator bottoms like the other non-volatile radionuclides.

To establish the input concentrations for ^{14}C or ^3H , it is assumed that no ^{14}C or ^3H is transferred to the DEP system in the SBS condensate stream or Plant Wash Vessel effluent stream and that the only input stream to the EMF containing ^{14}C or ^3H is the LAW feed flush stream to the DEP-VSL-00001 (Assumption 6.1.5).

After completion of a batch transfer to LCP-VSL-00001/2, the transfer line will be flushed to the DEP-VSL-00001. The total transfer volume and stream density are monitored prior to reaching LCP-VSL-00001/2 in order to detect when the stream composition changes from LAW feed to flush water. When flush water is first detected prior to LCP-VSL-00001/2, the valve alignment is changed to divert the flush water to DEP-VSL-00001. When the flow of flush water is stopped, the transfer line drains by gravity to DEP-VSL-00001 (Ref. 9.3, Section 2.6.2).

Based on the assumed flushing frequency of 18.8 hrs (Assumption 6.1.3), the applicable feed line flush volume to DEP-VSL-00001 is 1500 gallons (Input 2.4). The volume of residual feed material in the flush to DEP-VSL-00001 is estimated by multiplying the total LAW feed line flush volume (Input 2.4) by an assumed flush dilution factor (Assumption 6.1.2).

$$V_{\text{residual feed}} = V_{\text{flush}} * \text{Dilution Factor} * 3.785 \frac{\text{liters}}{\text{gal}} \quad \text{Equation 16}$$

Where:

$$\begin{aligned} V_{\text{residual feed}} &= \text{Volume of residual feed in a LAW feed line flush, in L} \\ V_{\text{flush}} &= \text{Total volume of LAW feed line flush, in gal (Input 2.4)} \\ \text{Dilution Factor} &= \text{Flush dilution factor (Assumption 6.1.2)} \end{aligned}$$

The total mass of ^{14}C and ^3H flushed annually to DEP-VSL-00001 is then calculated as follows using the maximum batch concentration, c_i (Equation 11), and the frequency of flushing to DEP-VSL-00001

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(Assumption 6.1.3). It is also assumed that the flush occurs continuously at the set frequency throughout an entire year (Assumption 6.2.5), so that the total number of flushes annually is the number of hours in a year multiplied by the frequency.

$$\bar{m}_{i,flush} = V_{residual\ feed} * c_i * F_{flush} * 8760 \frac{hr}{yr} \quad \text{Equation 17}$$

Where:

- $\bar{m}_{i,flush}$ = Mass of COPC i flushed to DEP-VSL-0001 annually, in g/yr
- $V_{residual\ feed}$ = Volume of residual feed in a LAW feed line flush, in L (Equation 16)
- c_i = Maximum feed vector batch concentration of COPC i , in g/L (Equation 11)
- F_{flush} = Frequency of LAW feed line flush, in 1/hr (Assumption 6.1.3)

5.1.4.2 Vapor Phase Radionuclide COPC Emissions

5.1.4.2.1 ¹⁴C Emissions

As a bounding assumption, it is assumed that the entire mass of ¹⁴C received in DEP-VSL-00001 annually is emitted to the DEP vessel ventilation system as it is processed through the DEP system (Assumption 6.2.4). The unabated emissions of ¹⁴C are then calculated as follows:

$$\bar{A}_{i,unabated} = \bar{m}_{i,flush} * SA_i \quad \text{Equation 18}$$

Where:

- $\bar{A}_{i,unabated}$ = Unabated activity of COPC i emitted per year, in Ci/year
- $\bar{m}_{i,flush}$ = Mass of COPC i flushed to DEP-VSL-0001 annually, in g/yr (Equation 17)
- SA_i = Specific Activity of COPC i , in Ci/g (Input 2.1, Attachment B)

For vapor phase COPCs with an F_v of 1, the DF is 1 through both the primary and secondary HEPA filter (Assumption 6.2.10). Therefore there is no emissions abatement provided by the HEPA filters for ¹⁴C.

5.1.4.2.2 ³H Emissions

The emissions of ³H are assumed to be controlled by the evaporator/condenser mass distribution ratios (MDRs) for ³H established in Ref. 9.19, Section 8 (Assumption 6.1.35). The MDR specifically represents the ratio of the evaporator/condenser overhead mass flowrate to the evaporator/condenser feed mass flowrate.

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$$MDR_i = \frac{\bar{m}_{overheads,i}}{\bar{m}_{feed,i}} \quad \text{Equation 19}$$

Where :

MDR_i = Mass distribution ratio of COPC i

$\bar{m}_{feed,i}$ = Mass flow rate for COPC i in the feed to the evaporator/condenser

$\bar{m}_{overheads,i}$ = Mass flow rate for COPC i in the evaporator/condenser overheads flow

MDRs for the FEP and TLP evaporators/condensers are calculated in Ref. 9.19, Section 8. These MDRs are assumed to apply to the DEP evaporator system (Assumption 6.1.13). For estimating ^3H emissions, the value for $\bar{m}_{i,flush}$ will be used for the evaporator feed stream, so $\bar{m}_{feed,i} = \bar{m}_{i,flush}$ (Assumption 6.1.36). For the evaporator and two condensers in series, the combined MDR is calculated by multiplying the individual MDRs.

$$MDR_{3H,combined} = MDR_{3H,evaporator} * MDR_{3H,primary\ condenser} * MDR_{3H,inter-condenser} \quad \text{Equation 20}$$

Note: The MDR of the after-condenser is 1 (Ref. 9.19, Section 8).

The unabated emissions of ^3H are then calculated as follows:

$$\bar{A}_{i,unabated} = \bar{m}_{i,flush} * MDR_{3H,combined} * SA_i \quad \text{Equation 21}$$

Where:

$\bar{A}_{i,unabated}$ = Unabated activity of COPC i emitted per year, in Ci/year

$\bar{m}_{i,flush}$ = Mass of COPC i flushed to DEP-VSL-0001 annually, in g/yr (Equation 17)

$MDR_{3H,combined}$ = Combined mass distribution ratio (Equation 20)

SA_i = Specific Activity of COPC i , in Ci/g (Input 2.1, Attachment B)

For vapor phase COPCs with an F_v of 1, the DF is 1 through both the primary and secondary HEPA filters (Assumption 6.2.10). Therefore there is no emissions abatement provided by the HEPA filters for ^3H .

5.1.5 ACV Exhaust System Radionuclide COPC Emissions

Air supplied to the LAW effluent process building, the LAW effluent drain tank building, and the LAW effluent utility building by the ACV supply system is exhausted by the ACV exhaust system. The ACV exhaust passes through a HEPA filtration system before being released from the EMF stack (Ref. 9.36). The unabated emissions for radionuclide COPCs from the ACV exhaust system are estimated based on a 2 month release of the unabated DEP vessel ventilation emissions into the ACV area of the EMF (Assumption 6.2.11). Abated emissions from the ACV exhaust system are based on the same particle and vapor phase HEPA DFs used for the DEP vessel ventilation system emissions (Assumption 6.2.10). Abated emissions will be calculated for both a single-stage and dual-stage HEPA filtration system in order to compare the effect on the emissions from the ACV exhaust system.

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$$\bar{A}_{i,unabated,ACV} = \bar{A}_{i,unabated} * \frac{2 \text{ months}}{12 \text{ months}} \quad \text{Equation 22}$$

Where:

$\bar{A}_{i,unabated,ACV}$ = Unabated activity of COPC i emitted per year from the ACV Exhaust system, in Ci/year

$\bar{A}_{i,unabated}$ = Unabated activity of COPC i emitted per year, in Ci/year (as determined in previous sections)

Note that since the ACV radionuclide emissions are based on a 2 month release from the DVP system into the ACV area, the total emissions of the DVP and ACV combined will double count this 2 month period (i.e. the total annual emissions for DVP and ACV are 117% of their actual value because the 2 month release period is counted for both ventilation systems).

5.1.6 Annual Possession Quantities

The annual possession quantities (APQs) represent the total annual amount of a radionuclide received in a system.

As discussed in Section 5.1.3, the emissions of all radionuclide COPCs, except ^{14}C and ^3H , were estimated based on the entrainment of particles. The estimate for entrainment conservatively assumed that the mass fraction of each radionuclide COPC remained at its maximum feed mass fraction from the Tank Farms throughout the DEP system (Assumption 6.1.1). For determination of the APQs for these radionuclides, the radionuclide concentrations received into the DEP system are set at the maximum feed vector batch concentration, c_i . The annual throughput of the DEP system is estimated based on a feed rate to the DEP evaporator of 10 gpm (Assumption 6.1.7) and an assumed annual evaporator availability of 100% (Assumption 6.2.13). The following equations are used to calculate the APQs for radionuclide COPCs emitted through entrainment:

$$APQ_i = c_i * SA_i * V_{evap,throughput} \quad \text{Equation 23}$$

Where:

APQ_i = Annual Possession Quantity of COPC i , Ci/yr

c_i = Maximum feed vector batch concentration of COPC i , in g/L (Equation 11)

SA_i = Specific Activity of COPC i , in Ci/g (Input 2.1)

$V_{evap,throughput}$ = Annual volume processed through DEP evaporator, in L (Equation 24)

$$V_{evap,throughput} = V_{evap,feed} * \frac{3.785 \text{ L}}{\text{gal}} * \frac{525600 \text{ min}}{\text{year}} \quad \text{Equation 24}$$

Where:

$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm (Assumption 6.1.7)

$V_{evap,throughput}$ = Annual volume processed through DEP evaporator, L (100% uptime based on Assumption 6.2.13)

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For vapor radionuclide COPC emissions, ^{14}C and ^3H , the mass flushed to DEP-VSL-00001 annually is calculated in Equation 17 and assumed to represent the entire amount of these COPCs received in the DEP system annually (Assumption 6.1.5). This mass is multiplied by the specific activity to determine the APQs for ^{14}C and ^3H .

$$APQ_i = \bar{m}_{i,flush} * SA_i \quad \text{Equation 25}$$

Where:

- APQ_i = Annual Possession Quantity of COPC i , Ci/yr
- $\bar{m}_{i,flush}$ = Mass of COPC i flushed to DEP-VSL-0001 annually, in g/yr (Equation 17)
- SA_i = Specific Activity of COPC i , in Ci/g (Input 2.1)

5.2 Organic COPC Emissions

Attachment A, Table A-2 shows the 309 organics tracked as COPCs at WTP, identified as feed compounds, PIC compounds, or both. The methodology for estimating feed organic emissions and PIC emissions will be described separately in the following sections.

5.2.1 Feed Organic COPC Emissions

Feed organic COPCs are organic compounds expected to be received in the waste feed from the Tank Farms. COPCs that are present in the feed and as PICs are evaluated as both (see Section 5.2.3).

5.2.1.1 Adjustment of Tank Farms Average Ratios

Ref. 9.2 provides Tank Farms Average ratios for feed organic COPCs, as well as 51 “non-COPC” organics, that were detected in tank farms sampling. The ratios are provided as g COPC / g TOC (total organic carbon) and as g COPC-as-Carbon / g TOC. An evaluation of the g COPC-as-Carbon / g TOC ratios for all organics (COPC and non-COPC) shows the ratios add up to 0.691 (Attachment C, Excel File “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*”, Worksheet “*Feed Organic COPCs - Calc*”, Cell D143), meaning the remaining fraction (0.309) of organic carbon is unaccounted for in the Tank Farms Average ratios. As an approximation to account for the unspiciated organic carbon, the “COPC-as-Carbon” ratios are scaled by a factor of (0.691^{-1}) , i.e. the remaining unspiciated organic carbon is assumed to be distributed proportionally to all of the organic compounds with ratios (Assumption 6.2.12).

$$\bar{c}_{i,scaled} = \frac{\bar{c}_i}{\sum \bar{c}_i} \quad \text{Equation 26}$$

Where:

- $\bar{c}_{i,scaled}$ = Scaled Tank Farms Average ratio for COPC i to account for unspiciated organic carbon, g COPC-as-Carbon / g TOC
- \bar{c}_i = Tank Farms Average ratio for COPC i , g COPC-as-Carbon / g TOC (Ref. 9.2)
- $\sum \bar{c}_i$ = Sum of all Tank Farms Average ratios (COPC and non-COPC) = 0.69

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Scaled values for the tank farm ratios, in units of g COPC / g TOC, are then calculated by multiplying $\bar{c}_{i,scaled}$ by the ratio of the mass of COPC i to the mass of COPC i as Carbon.

$$\bar{r}_{i,scaled} = \bar{c}_{i,scaled} * \frac{\bar{r}_i}{\bar{c}_i} \quad \text{Equation 27}$$

Where:

$\bar{r}_{i,scaled}$	= Scaled Tank Farms Average ratio for COPC i to account for unspiciated organic carbon, g COPC / g TOC
\bar{r}_i	= Tank Farms Average ratio for COPC i , g COPC / g TOC (Ref. 9.2)
$\bar{c}_{i,scaled}$	= Scaled Tank Farms Average ratio for COPC i to account for unspiciated organic carbon, g COPC-as-Carbon / g TOC (Equation 26)
\bar{c}_i	= Tank Farms Average ratio for COPC i , g COPC-as-Carbon / g TOC (Ref. 9.2)

There is a subset of feed organic COPCs that do not have Tank Farms Average ratios defined in Ref. 9.2, meaning these are COPCs for which no data is available. Therefore, this subset will have emissions of zero using the methodology based on Tank Farms Average ratios. However, this subset will be revisited in Section 5.2.4.2.2, in order to provide a bounding estimate of the emissions for these COPCs that is greater than zero.

5.2.1.2 Determination of Feed Vector TOC Values

The DFLAW Bounding Feed Vector includes separate values for TOC and oxalate ($C_2O_4^{2-}$). These values must be combined to have a true TOC value.

$$TOC_{adj} = (MW_c) * [(TOC_{batch}) + (\gamma) * (Ox_{batch})] * 1000 \frac{mol}{kmol} \quad \text{Equation 28}$$

Where:

TOC_{adj}	= Adjusted mass of TOC delivered to WTP in a feed vector batch, in g
MW_c	= Molecular weight of carbon g/mol (Input 2.6)
TOC_{batch}	= Moles of TOC delivered to WTP in a feed vector batch, in kmol (Ref. 9.2)
γ	= Moles of carbon per mole of oxalate (2 kmol/kmol)
Ox_{batch}	= Moles of oxalate delivered to WTP in a feed vector batch, in kmol (Ref. 9.2)

5.2.1.3 COPC Maximum Batch Masses, Mass Fractions, and Concentrations

Using the adjusted mass of TOC in each batch (Equation 28), the average, minimum, and maximum values for adjusted mass of TOC are calculated (Attachment G).

The maximum batch mass of each feed organic COPC is then calculated as follows:

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$$m_i = \bar{r}_{i,scaled} * TOC_{adj,max} \quad \text{Equation 29}$$

Where:

- m_i = Maximum feed vector batch mass of COPC i , in g
 $\bar{r}_{i,scaled}$ = Scaled Tank Farms Average ratio for COPC i to account for unspciated organic carbon, g COPC / g TOC (Equation 27)
 $TOC_{adj,max}$ = Maximum batch adjusted mass of TOC delivered to WTP in a feed vector batch, in g (Equation 28)

The mass fraction, x_i , of each feed organic COPC is then calculated using Equation 10. For conservatism, $m_{batch,avg}$ is used in Equation 10 (Assumption 6.1.34).

The concentration, c_i , of each feed organic COPC is calculated using Equation 11. For conservatism, $V_{batch,avg}$ is used in Equation 11 (Assumption 6.1.34).

5.2.1.4 Other Physical Properties

One measure of the volatility of a COPC is the vapor phase partitioning coefficient, F_v , which is used to classify the phase type of COPCs in an off-gas stream as follows (Ref. 9.4, Section 4.0):

- $F_v = 1.0$; phase type = vapor
- $0.05 \leq F_v < 1.0$; phase type = particle-bound
- $F_v < 0.05$; phase type = particle

COPCs with particle-bound phase type will partition as both vapor and particle according to the F_v value. For example, F_v value of 0.95 indicates that the constituent is 95% vapor and 5% particle in an off-gas stream.

Physical properties for organic COPCs have been compiled in Ref. 9.15, Attachment A. The F_v values, molecular weights, and Henry's Law constants of the feed organic COPCs are extracted from Ref. 9.15, Attachment A for use in this calculation (Assumption 6.1.6).

5.2.1.5 Vapor Phase Feed Organic COPC Emissions

To establish the input concentrations for feed organic COPCs, it is assumed that no feed organics are transferred to the DEP system in the SBS condensate stream or Plant Wash Vessel effluent stream and that the only input stream to the EMF containing feed organics is the LAW feed flush stream to DEP-VSL-00001 (Assumption 6.1.37).

After completion of a batch transfer to LCP-VSL-00001/2, the transfer line will be flushed to DEP-VSL-00001. The total transfer volume and stream density are monitored prior to reaching LCP-VSL-00001/2 in order to detect when the stream composition changes from LAW feed to flush water. When flush water

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is first detected prior to LCP-VSL-00001/2, the valve alignment is changed to divert the flush water to DEP-VSL-00001. When the flow of flush water is stopped, the transfer line drains by gravity to DEP-VSL-00001 (Ref. 9.3, Section 2.6.2).

The volume of residual feed in the flush, $V_{residual\ feed}$, was previously calculated using Equation 16.

The total mass of each feed organic COPC flushed annually to DEP-VSL-00001, $\bar{m}_{i,flush}$, is then calculated using Equation 17.

As a bounding assumption, it is assumed that the entire vapor fraction of each feed organic COPC received in DEP-VSL-00001 annually is emitted to the DEP vessel ventilation system as it is processed through the DEP system (Assumption 6.2.16). The unabated emissions of feed organic COPCs is then calculated as follows:

$$\bar{m}_{i,vap,unabated} = \bar{m}_{i,flush} * F_{v,i} * \frac{1\ year}{31,536,000\ seconds} \quad \text{Equation 30}$$

Where:

$\bar{m}_{i,vap,unabated}$	=	Unabated vapor phase emissions of COPC i , in g/sec
$\bar{m}_{i,flush}$	=	Mass of COPC i flushed to DEP-VSL-0001 annually, in g/yr (Equation 17)
$F_{v,i}$	=	Vapor phase partitioning coefficient of COPC i (Section 5.2.1.4)

For vapor phase COPCs with an F_v of 1, the DF is 1 through both the primary and secondary HEPA filter (Assumption 6.2.10). Therefore there is no emissions abatement provided by the HEPA filters for feed organic COPCs emitted in the vapor phase ($\bar{m}_{i,vap,abated} = \bar{m}_{i,vap,unabated}$).

5.2.1.6 Particle Phase Feed Organic COPC Emissions

Feed organic COPCs with an F_v value less than 1 will have particulate phase emissions. For the estimation of particle emissions, the maximum feed vector batch mass fraction of COPC i , x_i , (calculated in Section 5.2.1.3) is conservatively assumed to represent the mass fraction of feed organic COPC i throughout the DEP system (Assumption 6.1.1). The entrained mass flowrate of feed organic COPCs from the DVP system are calculated using the total mass flowrate of entrained material (Equation 12) and the following equation:

$$\bar{m}_{i,entrained} = \bar{m}_{tot,entrained} * x_i * (1 - F_{v,i}) \quad \text{Equation 31}$$

Where:

$\bar{m}_{i,entrained}$	=	Entrained mass flowrate of COPC i , in g/min
$\bar{m}_{tot,entrained}$	=	Total mass flowrate of entrained material, in g/min (Equation 12)
$F_{v,i}$	=	Vapor phase partitioning coefficient of COPC i (Section 5.2.1.4)

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The value for $\bar{m}_{i,entrained}$ (in g/min) calculated from Equation 31 is converted to g/sec and represents the unabated particulate emissions of feed organic COPC i , $\bar{m}_{i,part,unabated}$.

$$\bar{m}_{i,part,unabated} = \bar{m}_{i,entrained} * \frac{1 \text{ min}}{60 \text{ sec}} \quad \text{Equation 32}$$

Where :

$\bar{m}_{i,part,unabated}$ = Unabated particulate emissions of COPC i , in g/sec

$\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC i , in g/min (Equation 31)

The abated emissions are then calculated using a modification to Equation 15, based on mass emitted instead of activity emitted.

$$\bar{m}_{i,part,abated} = \frac{\bar{m}_{i,part,unabated}}{DF_{HEPA,primary} * DF_{HEPA,secondary}} \quad \text{Equation 33}$$

Where:

$\bar{m}_{i,part,abated}$ = Abated particulate emissions of COPC i , in g/sec

$\bar{m}_{i,part,unabated}$ = Unabated particulate emissions of COPC i , in g/sec (Equation 32)

$DF_{HEPA,primary}$ = Decontamination factor of primary HEPA filter (Assumption 6.2.10)

$DF_{HEPA,secondary}$ = Decontamination factor of secondary HEPA filter (Assumption 6.2.10)

5.2.2 PIC COPC Emissions

PICs are COPCs generated in the melter through combustion of organic material in the melter feed. The following methodology is used to estimate the emissions of PICs from the DVP system.

5.2.2.1 PIC Generation Rates

The generation rates of PICs in the melter have been studied through R&T (Research and Technology) testing. Generation rates for PICs detected in testing at the Vitreous State Laboratory of the Catholic University of America (VSL) are reported in Ref. 9.15, Table 3. These generation rates are used to estimate the emissions of PICs from the DVP system (Assumption 6.2.26).

First, the list of PICs with generation rates in Ref. 9.15, Table 3 is cross referenced with the list of PIC COPCs in Attachment A, Table A-2, and generation rates are assigned to the COPCs that occur in both lists. Generation rates are given in units of mg generated / mg melter feed TOC. Values calculated in the Process Inputs Basis of Design (PIBOD) (Ref. 9.22) model runs for TOC in the LAW Melter Feed Process system stream (LFP04) were extracted for use in this calculation (Attachment F, Table F-1). The maximum value for melter feed TOC in Attachment F will be used to provide a conservative value for the amount of PIC generation. This LAW melter feed TOC value is assumed to apply to the DFLAW operating scenario (Assumption 6.1.15)

As an initial screening, PICs with an F_v value of 1 are assumed to pass through the SBS with a DF of 1 and are emitted entirely through the LAW offgas system (Assumption 6.2.15). This means these vapor phase PICs will not be captured in the SBS, and therefore not transferred to the DEP system through the

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SBS condensate stream (RLD21). Therefore, these vapor phase PICs will therefore have emissions of zero using the following methodology. However, these vapor phase PICs will be revisited in Section 5.2.4.2.1, in order to provide a bounding estimate of emissions for these COPCs that is greater than zero.

Next, the mass flowrates leaving the melter (in g/sec) are calculated for PIC COPCs that have generation rates reported in Ref. 9.15, Table 3.

$$\bar{m}_{melter,i} = GR_{PIC,i} * TOC_{MF,max} * \frac{1000 \text{ g}}{\text{kg}} * \frac{1 \text{ hr}}{3600 \text{ sec}} \quad \text{Equation 34}$$

Where :

- $\bar{m}_{melter,i}$ = Mass flowrate of PIC COPC i generated in the melter, in g/sec
- $GR_{PIC,i}$ = Generation rate of PIC COPC i , in mg (or g) PIC generated / mg (or g) melter feed TOC (Ref. 9.15, Table 3)
- $TOC_{MF,max}$ = Maximum mass flowrate of TOC in melter feed stream LFP04 from PIBOD model runs, in kg/hr (Assumption 6.1.15)

As a conservative assumption, if a particle or particle-bound PIC COPC does not have a generation rate in Ref. 9.15, Table 3, it is assigned the maximum $GR_{PIC,i}$ value for a particle or particle-bound PIC COPC for calculation of Equation 34 (Assumption 6.2.17).

5.2.2.2 PIC COPC Emissions

Next, the amount of each PIC COPC captured in the SBS as particulate is calculated. For conservatism, the entire fraction of each PIC COPC that exists as particulate, represented by $(1 - F_{v,i})$, is assumed to be captured in the SBS (Assumption 6.2.18).

$$\bar{m}_{SBS,i} = \bar{m}_{melter,i} * (1 - F_{v,i}) \quad \text{Equation 35}$$

Where :

- $\bar{m}_{SBS,i}$ = Mass flowrate of PIC COPC i captured in the SBS, in g/sec
- $\bar{m}_{melter,i}$ = Mass flowrate of PIC COPC i generated in the melter, in g/sec (Equation 34)
- $F_{v,i}$ = Vapor phase partitioning coefficient of COPC i (Section 5.2.1.4)

The SBS condensate is transferred from the SBS to RLD-VSL-00005. The contents of RLD-VSL-00005 are transferred once every 24 hours to DEP-VSL-00002 with a transfer volume of 10,700 gallons (Assumptions 6.2.19 and 6.2.20, respectively). This transfer stream is designated RLD21 in the PFD (Ref. 9.5). The mass flowrate of stream RLD21 is calculated, and then subsequently used to calculate the mass fraction of each PIC COPC in stream RLD21.

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$$\bar{m}_{RLD21} = V_{RLD21} * \rho_{RLD21} * F_{RLD21} * \frac{hr}{3600 sec} * \frac{3.785 L}{1 gal} \quad \text{Equation 36}$$

Where :

- \bar{m}_{RLD21} = Mass flowrate of stream RLD21, in g/sec
- V_{RLD21} = Transfer volume of stream RLD21, in gal (Assumption 6.2.20)
- ρ_{RLD21} = Density of stream RLD21 from PIBOD, in g/L (From Input 2.14)
- F_{RLD21} = Frequency of transfer from RLD-VSL-00005 to DEP-VSL-00002, in 1/hr (Assumption 6.2.19)

$$x_{RLD21,i} = \frac{\bar{m}_{SBS,i}}{\bar{m}_{RLD21}} \quad \text{Equation 37}$$

Where :

- $x_{RLD21,i}$ = Mass fraction of PIC COPC i in Stream RLD21
- \bar{m}_{RLD21} = Mass flowrate of stream RLD21, in g/sec (Equation 36)
- $\bar{m}_{SBS,i}$ = Mass flowrate of PIC COPC i captured in the SBS, in g/sec (Equation 35)

For the estimation of particle emissions, the mass fraction of PIC COPC i in Stream RLD21, $x_{RLD21,i}$, is assumed to represent the mass fraction of PIC COPC i throughout the DEP system (Assumption 6.1.1). The particulate emissions of PIC COPCs from the DVP system are calculated using Equation 12 and Equation 13, previously defined in Section 5.1.3. In Equation 13, $x_{RLD21,i}$ is substituted for x_i .

Next, values for $\bar{m}_{i,part,unabated}$ and $\bar{m}_{i,part,abated}$ are calculated using Equation 32 and Equation 33, previously defined in Section 5.2.1.6.

5.2.3 Feed/PIC Organic COPC Emissions

In Attachment A, Table A-2, a subset of organic COPCs are identified as being present as both Feed Organics and PICs. Feed/PIC COPCs with an F_v value less than 1 could have particulate emissions based on the methodology described in Sections 5.2.1.6 and 5.2.2.2. The particulate emissions reported in the results for these Feed/PIC COPCs will be the sum of the particulate emissions calculated in Sections 7.2.1.6 and 7.2.2.2.

5.2.4 Organic COPC Summary and Comparison to De Minimis Emissions Limits

The results from Sections 5.2.1, 5.2.2, and 5.2.3 are presented in summary tables (Table 8-4 and Table 8-5). The summary table for feed organic COPCs (Sections 5.2.1 and 5.2.3) shows results for vapor phase, particle phase, and total emissions for each feed organic COPC. The PIC COPC summary shows particle phase emissions.

Next, the total abated emissions values are compared to de minimis emissions limits for toxic air pollutants (TAPs) established in WAC 173-460-150 (Input 2.13). Each TAP has a de minimis value (lb/averaging period) and an averaging period (1-hour, 24-hours, or 1 year).

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De minimis emissions are defined in Ref. 10.8 as “trivial levels of emissions that do not pose a threat to human health or the environment. The de minimis emissions threshold values are listed in WAC 173-460-150.”

The de minimis values are all converted to units of lb/year.

$$\bar{m}_{i,dm\ standard} = \begin{cases} \bar{m}_{i,dm} , & \text{if averaging period} = 1 \text{ year} \\ \bar{m}_{i,dm} * 365 , & \text{if averaging period} = 24 \text{ hours} \\ \bar{m}_{i,dm} * 8760 , & \text{if averaging period} = 1 \text{ hour} \end{cases} \quad \text{Equation 38}$$

Where:

$\bar{m}_{i,dm\ standard}$ = De minimis emissions limit for COPC i , standardized to lb/yr
 $\bar{m}_{i,dm}$ = De minimis emissions limit for COPC i , lb/averaging period (Input 2.13)

Next, the values for $\bar{m}_{i,total,unabated}$ (Table 8-4 and Table 8-5) converted from g/sec to lb/year, for a standard comparison with the de minimis values.

$$\bar{m}_{i,total,unabated} \left(\frac{lb}{yr} \right) = \bar{m}_{i,total,unabated} \left(\frac{g}{sec} \right) * \frac{31,536,000 \text{ seconds}}{1 \text{ year}} * \frac{lb}{453.5924 \text{ grams}}$$

If any values for $\bar{m}_{i,total,unabated} \left(\frac{lb}{yr} \right)$ are greater than $\bar{m}_{i,dm\ standard}$, that COPC is evaluated using a more rigorous approach for estimating the vapor emissions (Section 5.2.4.1).

5.2.4.1 Henry’s Law Analysis

The subset of feed organic COPCs that exceed their de minimis emissions limit, based on the first-pass bounding assumption of complete emission of the vapor fraction of the COPC mass received in the feed line flush (Assumption 6.2.16), are evaluated a second time using a Henry’s Law analysis.

First, the concentration of each feed organic COPC (in g/L) is calculated based on the amount received in the feed line flush to DEP-VSL-00001 and the DEP evaporator annual throughput volume. The annual throughput is determined based on Assumptions 6.1.7 and 6.2.13.

$$c_{i,flush} = \frac{\bar{m}_{i,flush}}{V_{evap,throughput}} \quad \text{Equation 39}$$

Where:

$c_{i,flush}$ = Concentration of COPC i based on amount received in feed line flush, g/L
 $\bar{m}_{i,flush}$ = Mass of COPC i flushed to DEP-VSL-00001 annually, in g/yr (Equation 17)
 $V_{evap,throughput}$ = Annual volume processed through DEP evaporator, in L (Equation 24)

Each COPC is assumed to be at the concentration, $c_{i,flush}$, throughout the DEP system (Assumption 6.1.11).

The equation for Henry’s Law is (Ref. 10.9, Equation 1):

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$$k_{H,i} = \frac{c_i}{p_i} \quad \text{Equation 40}$$

Where:

$$k_H = \text{Henry's Law constant of COPC } i, \text{ in } \frac{\text{mol}}{\text{m}^3 \cdot \text{Pa}}$$

$$c_i = \text{Concentration of COPC } i \text{ in the aqueous phase, in mol/m}^3 \text{ (Equation 43)}$$

$$p_i = \text{Partial pressure of COPC } i \text{ in the vapor phase, in Pa (Equation 41)}$$

The equation for partial pressure using Dalton's Law is (Ref. 10.3, Page 43-2, Equation 43.11):

$$p_i = y_i * P \quad \text{Equation 41}$$

Where:

$$y_i = \text{Mole fraction COPC } i \text{ in the vapor phase}$$

$$P = \text{Total pressure of the vapor space, in Pa}$$

The Henry's Law constants used in this calculation (Section 5.2.1.4) have units of $\frac{\text{atm} \cdot \text{m}^3}{\text{mol}}$, which is the reciprocal of the units in Equation 40, therefore the equation for Henry's Law applicable to this calculation is:

$$k'_{H,i} = k_{H,i}^{-1} = \frac{p_i}{c_i}, \text{ using units of } \frac{\text{atm} \cdot \text{m}^3}{\text{mol}} \quad \text{Equation 42}$$

The concentration of COPC i in the aqueous phase, c_i (with units of mol/m³), can be defined based on other variables previously established in this calculation.

$$c_i = \frac{c_{i,flush}}{MW_i} * \frac{1000 \text{ liters}}{\text{m}^3} \quad \text{Equation 43}$$

Where:

$$c_{i,flush} = \text{Concentration of COPC } i \text{ based on amount received in feed line flush, g/L (Equation 39)}$$

$$MW_i = \text{Molecular weight of COPC } i, \text{ in g/mol (Ref. 9.15, Attachment A)}$$

Next, substitute Equation 41 and Equation 43 into Equation 42 and rearrange to solve for the vapor phase mole fraction, y_i .

$$k'_{H,i} = \frac{p_i}{c_i} = \frac{y_i * P}{\frac{c_{i,flush} * 1000 \text{ liters}}{MW_i * \text{m}^3}}$$

$$y_i = \frac{k'_{H,i} * \frac{c_{i,flush} * 1000 \text{ liters}}{MW_i * \text{m}^3}}{P} \quad \text{Equation 44}$$

Equation 44 is solved for two separate cases:

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Case 1: Vessel Vent Streams

Case 2: Evaporator Vent Stream

5.2.4.1.1 Case 1: Vessel Vent Streams

The vapor emissions from all vessel vent streams, except for the vent from the evaporator system, are estimated using a combined Henry's Law analysis. The pressure in the vapor space, P_{vessel} , for all DEP vessels is 0.9622 atm (Assumption 6.1.10). Equation 44 is solved for the vapor phase mole fractions, y_i , in the DEP vessel vapor spaces. Next, the combined mass flow rate of COPC i from all DEP vessel vents is calculated based on the total mass flow rate of the vessel vent system, $\bar{m}_{tot,vent}$.

$$\bar{m}_{vapor,vent,i} = \frac{\bar{m}_{tot,vent} * \frac{453.5924 \text{ g} * \text{hour}}{\text{lb} * 3600 \text{ sec}}}{MW_{air}} * y_i * MW_i \quad \text{Equation 45}$$

Where:

- $\bar{m}_{vapor,vent,i}$ = Vapor phase mass flow rate of COPC i in vessel vent stream, g/sec
- $\bar{m}_{tot,vent}$ = Total mass flowrate of the DVP system, in lb/hr (Assumption 6.1.4)
- MW_{air} = Average molecular weight of air, g/mol (Input 2.8)
- y_i = Mole fraction COPC i in the vapor phase (From Equation 44)
- MW_i = Molecular weight of COPC i (Ref. 9.15, Attachment A)

Note: $\bar{m}_{tot,vent}$ is the total flow of the vessel vent exhaust stream and includes the vent stream from the evaporator system. The total flow is used in Equation 45 for conservatism (Assumption 6.1.12).

5.2.4.1.2 Case 2 Evaporator Vent Stream

The vapor emissions from the evaporator system vent are estimated separately from the vessel vent streams due to differing operating pressures and the inclusion of condensers in the evaporator system vent. The evaporator system vents from the after-condenser. The vapor emissions from the evaporator separator vessel are estimated using a Henry's Law analysis. The pressure, P_{evap} , in the evaporator vessel is 0.0967 atm (Assumption 6.1.9). Equation 44 is solved for the vapor phase mole fractions, y_i , in the evaporator vessel overheads stream. Next, the mass flow rate of COPC i in the evaporator overheads stream is calculated based on the total volumetric flow rate of the evaporator overheads stream.

$$\bar{m}_{vapor,evap,i} = \frac{\bar{V}_{tot,evap} * \frac{3.785 \text{ L}}{\text{gal}} * \rho_{water} * \frac{\text{min}}{60 \text{ sec}}}{MW_{water}} * y_i * MW_i \quad \text{Equation 46}$$

Where:

- $\bar{m}_{vapor,evap,i}$ = Vapor phase mass flow rate of COPC i in evaporator overheads stream, in g/sec
- $\bar{V}_{tot,evap}$ = Total volumetric flowrate of the evaporator overheads stream, in gpm (Assumption 6.1.8)
- MW_{water} = Molecular weight of water, in g/mol (Input 2.7)
- ρ_{water} = Density of water, in g/L (Equation 47)
- y_i = Mole fraction COPC i in the vapor phase (Equation 44)
- MW_i = Molecular weight of COPC i (Ref. 9.15, Attachment A)

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The density of water is calculated using the following correlation from Ref. 9.18, Section 8. The evaporator overheads stream is assumed to have the physical properties of water (Assumption 6.2.14).

$$\rho_{water} = -3.564E^{-3} * T_L^2 - 6.954E^{-2} * T_L + 1001 \quad \text{Equation 47}$$

Where:

$$\begin{aligned} \rho_{water} &= \text{Density of water, in kg/m}^3 \text{ or g/L} \\ T_{evap} &= \text{Normal operating temperature of the DEP evaporator, } ^\circ\text{C (Assumption 6.1.9)} \end{aligned}$$

Next, the separation in the primary, inter-, and after-condensers is approximated using condenser MDRs. MDRs for the FEP and TLP evaporators/condensers are calculated in Ref. 9.19, Section 8. These MDRs are assumed to apply to the DEP evaporator system (Assumption 6.1.13). The primary and inter-condenser MDRs for volatile organic compounds (VOCs) in Ref. 9.19 are assumed to apply to all COPCs being evaluated in Case 2 (Assumption 6.1.14). The feed stream to the primary condenser is the evaporator overheads stream, so $\bar{m}_{feed,i} = \bar{m}_{vapor,evap,i}$. For the two condensers in series, the combined MDR is calculated by multiplying the individual MDRs.

$$MDR_{VOC,combined} = MDR_{VOC,primary\ condenser} * MDR_{VOC,inter-condenser} \quad \text{Equation 48}$$

Note: The MDR of the after-condenser is 1 (Ref. 9.19, Section 8).

The mass flowrate of COPC i leaving in the evaporator system vent is then calculated as follows:

$$\bar{m}_{vapor,evap,tot,i} = MDR_{VOC,combined} * \bar{m}_{vapor,evap,i} \quad \text{Equation 49}$$

Where :

$$\begin{aligned} \bar{m}_{vapor,evap,vent,i} &= \text{Vapor phase mass flowrate of COPC } i \text{ in the evaporator vent stream, g/sec} \\ MDR_{VOC,combined} &= \text{VOCs combined mass distribution ratio for primary and inter-condensers} \\ &\quad \text{(Equation 48)} \\ \bar{m}_{vapor,evap,i} &= \text{Vapor phase mass flow rate of COPC } i \text{ in evaporator overheads stream, in g/sec} \\ &\quad \text{(Equation 46)} \end{aligned}$$

5.2.4.1.3 Henry's Law Analysis Emissions and Mass Check

The unabated vapor emissions based on the Henry's Law analyses from Case 1 and Case 2 are combined to give the total unabated vapor emissions.

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$$\bar{m}_{unabated, Henry, i} = \bar{m}_{vapor, vent, i} + \bar{m}_{vapor, evap_tot, i} \quad \text{Equation 50}$$

Where :

$\bar{m}_{unabated, Henry, i}$ = Unabated vapor emissions of COPC i , in g/sec

$\bar{m}_{vapor, evap_tot, i}$ = Vapor phase mass flowrate of COPC i in the evaporator vent stream, g/sec (Equation 49)

$\bar{m}_{vapor, vent, i}$ = Vapor phase mass flow rate of COPC i in vessel vent stream, g/sec (Equation 45)

In some cases, $\bar{m}_{unabated, Henry, i}$ may exceed $\bar{m}_{i, vap, unabated}$ (Equation 30). Since $\bar{m}_{i, vap, unabated}$ is based on the entire mass of the vapor phase of a COPC that is flushed to the DEP system being emitted, values of $\bar{m}_{unabated, Henry, i}$ that exceed $\bar{m}_{i, vap, unabated}$ will be capped at the value for $\bar{m}_{i, vap, unabated}$.

5.2.4.2 Adjustment of COPCs with Zero Emissions

There are two subsets of organic COPCs that have emissions reported as zero based on the methodology described in the preceding sections. The first subset is vapor phase PIC COPCs that are assumed to not be captured in the SBS, and therefore not transferred to the DEP system. The second subset is the feed organic COPCs that do not have Tank Farms Average Ratios defined in Ref. 9.2.

5.2.4.2.1 Adjustment of PIC COPCs with Zero Emissions

The subset of PIC COPCs with vapor phase type ($F_v = 1$) have emissions estimated as 0 g/sec based on Assumption 6.2.15. Assumption 6.2.15 states that vapor phase COPCs have a DF of 1 in the SBS, meaning the entire amount entering the SBS passes through the SBS without being scrubbed from the off-gas stream. Since these vapor phase PIC COPCs are not captured in the SBS, they are not transferred to the DEP system in the SBS condensate stream (RLD21).

In order to assign this subset of PIC COPCs a bounding emissions estimate greater than 0 g/sec, they are assumed to be emitted at the average unabated particulate emissions rate for PIC COPCs (Assumption 6.2.27). The unabated particulate emissions rate for PIC COPCs was calculated using Equation 32. The average of the non-zero unabated particulate emissions rates is calculated, and this average value is assigned to all vapor phase PIC COPCs.

5.2.4.2.2 Adjustment of Feed Organic COPCs with Zero Emissions

The subset of the feed organic COPCs that were not detected in Tank Farms sampling and therefore do not have Tank Farms Average Ratios defined in Ref. 9.2 initially have emissions estimates of 0 g/sec. In order to assign this subset of feed organic COPCs a bounding emissions estimate greater than 0 g/sec, they are assumed to be emitted at the average unabated vapor emissions rate for feed organic COPCs with Tank Farms Average Ratios (Assumption 6.2.28). The unabated vapor emissions rate for feed organic COPCs is reported in the Feed Organic COPC summary table (Table 8-4). In the summary table, feed organic COPCs with Tank Farms Average Ratios are identified as having non-zero values for vapor emissions. The average unabated vapor emissions rate for feed organic COPCs with Tank Farms Average

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Ratios is calculated, and this average value is assigned as the unabated vapor emissions rate for all feed organic COPCs without Tank Farms Average Ratios.

5.3 Inorganic COPC Emissions

Attachment A, Table A-3 shows the 54 inorganic compounds tracked as COPCs at WTP. Table A-3 designates each inorganic COPC as either a feed compound or a stack compound. Feed compounds are received in the waste feed stream to the plant, while stack compounds are generated during processing within the plant.

5.3.1 Feed Inorganic COPC Emissions

5.3.1.1 COPC Maximum Batch Masses, Mass Fractions, and Concentrations

The maximum batch mass for the feed inorganic COPCs is determined using the Tank Farms Average ratios (g COPC / g Na) and the DFLAW Bounding Feed Vector maximum sodium batch. The Tank Farms Average ratios (g COPC / g Na) are provided in Ref. 9.2. The Tank Farms Average ratios are assumed to be applicable to this analysis (Assumption 6.2.1). The DFLAW Bounding Feed Vector is provided in Ref. 9.2 and used in this calculation (Assumption 6.2.2). The values for the amount of sodium (in kmol) in each batch during the DFLAW campaign are extracted from the DFLAW Bounding Feed Vector and then the average, minimum, and maximum values are calculated.

The maximum batch mass of each feed inorganic COPC is calculated as follows:

$$m_i = r_i * n_{Na,max} * MW_{Na} * 1000 \frac{mol}{kmol} \quad \text{Equation 51}$$

Where:

- m_i = Maximum feed vector batch mass of COPC i , in g
- r_i = Tank Farms Average ratio of COPC i , in g COPC / g Na (Ref. 9.2)
- $n_{Na,max}$ = Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmols (Attachment G)
- MW_{Na} = Molecular weight of sodium, in g/mol (Input 2.5)

A conservative value for the mass fraction, x_i , of each feed inorganic COPC is then calculated using Equation 10.

A conservative value for the concentration, c_i , of each feed inorganic COPC is calculated using Equation 11.

5.3.1.2 Particle Phase Feed Inorganic COPC Emissions

Feed inorganic COPCs (with the exception of ammonia, mercury, and cyanide) are emitted through entrainment as particles (Assumption 6.2.21). For the estimation of particle emissions, the maximum feed vector batch mass fraction of COPC i , x_i , (calculated in Section 5.3.1.1) is conservatively assumed to represent the mass fraction of feed inorganic COPC i throughout the DEP system (Assumption 6.1.1).

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The particulate emissions of feed inorganic COPCs from the DVP system are calculated using Equation 12 and Equation 13 (previously defined in Section 5.1.3).

The value for $\bar{m}_{i,entrained}$ (in g/min) calculated from Equation 13 is converted to g/sec using Equation 32 (defined in Section 5.2.1.6) and represents the unabated particulate emissions of feed inorganic COPC i , $\bar{m}_{i,part,unabated}$.

The abated emissions are then calculated using Equation 33 (defined in Section 5.2.1.6).

5.3.1.2.1 Mercury

Mercury emissions depend on the speciation of the mercury in the waste streams. The main species present in the Tank Farms are elemental mercury (Hg), mercury oxide (HgO), mercury chloride (HgCl₂), and calomel (Hg₂Cl₂). Hg is a volatile metal, HgCl₂ is semivolatile, and HgO and Hg₂Cl₂ are non-volatile (Ref. 9.29, Section 7.2.3). In addition, monomethyl mercury (CH₃Hg⁺) and dimethyl mercury [(CH₃)₂Hg] have the potential to form in WTP waste streams due to the reaction between mercury and organic species, with monomethyl mercury being non-volatile and dimethyl mercury being volatile (Ref. 9.24).

The mercury received in the DEP system is assumed to be non-volatile (HgO) and emitted through entrainment (Assumption 6.1.32).

For the calculation of mercury emissions from the DEP system due to entrainment, a methodology similar to the one in Sections 5.3.1.1 and 5.3.1.2 for other particle phase feed inorganic COPCs is used. This includes an assumption that the mass fraction of Hg is constant throughout the DEP system at a maximum feed value (Assumption 6.1.33). Using this method, the maximum feed vector mass fraction, x_{Hg} , will be compared to the maximum feed mass fraction calculated using the ICD-30 limit for mercury and if the ICD-30 mass fraction is greater, it will be used for greater conservatism.

The maximum feed vector batch mass of Hg using the ICD-30 limit is calculated as follows:

$$m_{Hg,ICD30} = c_{Hg,ICD30} * n_{Na,max} * 1000 \frac{mol}{kmol} * MW_{Hg} \quad \text{Equation 52}$$

Where:

- $m_{Hg,ICD30}$ = Maximum feed vector batch mass of Hg using ICD-30 limit, in g
- $c_{Hg,ICD30}$ = ICD-30 limit for Hg, in mol Hg / mol Na (Input 2.19)
- $n_{Na,max}$ = Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmols (Attachment G)
- MW_{Hg} = Molecular weight of Hg, in g/mol (Input 2.10)

If $m_{Hg,ICD30}$ is greater than the mass of Hg calculated from Equation 51, then it is used in the calculation of emissions due to entrainment using Equation 13, Equation 32, and Equation 33.

Vapor emissions of dimethyl mercury will be calculated separately (see Section 5.3.1.3.3).

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5.3.1.3 Vapor Phase Feed Inorganic COPC Emissions

Ammonia, cyanide, carbon disulfide, and dimethyl mercury are emitted in the vapor phase (Assumptions 6.2.21, 6.2.16, and 6.2.23). Note that carbon disulfide is a feed organic COPC per Ref. 9.1 and has been evaluated as an organic COPC in past WTP emissions estimates (Ref. 9.14). The calculation of the emissions estimate for carbon disulfide will be conducted within the vapor phase feed inorganic COPC section because the Tank Farm Average ratio for carbon disulfide is reported as an inorganic COPC in Ref. 9.2, with units of g COPC / g Na. While the calculation for carbon disulfide will be carried out with the inorganic COPCs, the results for carbon disulfide will be reported with the feed organic COPC results.

5.3.1.3.1 Carbon Disulfide and Cyanide

Carbon disulfide (CS₂) and cyanide (CN) will be evaluated using the methodology for vapor phase feed organic COPCs described in Section 5.2.1.5. Also, as noted above, the results for carbon disulfide will be reported with feed organic COPCs and not feed inorganic COPCs.

5.3.1.3.2 Ammonia

Ammonia (NH₃) will be evaluated using the methodology for vapor phase feed organic COPCs described in Section 5.2.1.5, with an additional step to account for ammonia received in the caustic scrubber effluent stream (LVP21). The vapor phase emissions calculated using Section 5.2.1.5 represent complete emission of all NH₃ received in the feed line flush stream to DEP-VSL-00001. Since the caustic scrubber effluent is another DEP inlet stream containing appreciable amounts of NH₃, emissions of NH₃ from DEP-VSL-00004A/B and DEP-VSL-00005A/B must account for the additional NH₃.

Emissions of NH₃ from DEP-VSL-00004A/B and DEP-VSL-00005A/B will be estimated using a Henry's Law analysis.

The volume transferred annually from LVP-TK-00001 to DEP-VSL-00004A/B in stream LVP21 is calculated using the batch volume of LVP-TK-00001 and the transfer frequency.

$$V_{LVP21,annual} = V_{LVP21,batch} * F_{LVP} * 3.785 \frac{L}{gal} * 8760 \frac{hr}{year} \quad \text{Equation 53}$$

Where:

$V_{LVP21,annual}$ = Annual volume transferred in LVP21, in L (Assumption 6.2.22)

$V_{LVP21,batch}$ = Batch transfer volume from LVP-TK-00001 to DEP-VSL-00004A/B, in gal (Input 2.15)

F_{LVP21} = Frequency of LVP-TK-00001 transfer, in 1/hr (Input 2.16)

The mass of NH₃ transferred annually to DEP-VSL-00004A/B is then calculated using the following equation:

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$$m_{LVP21,NH_3} = V_{LVP21,annual} * \rho_{LVP21} * x_{LVP21,NH_3} \quad \text{Equation 54}$$

Where:

- m_{LVP21,NH_3} = Annual mass of NH₃ in LVP21, in g
- $V_{LVP21,annual}$ = Annual volume transferred in LVP21, in L (Equation 53)
- ρ_{LVP21} = Density of LVP21, in g/L (Input 2.17)
- x_{LVP21,NH_3} = Mass fraction of NH₃ in LVP21 (Assumption 6.1.16) (Attachment F, Table F-2)

The volume of fluid received annually in DEP-VSL-00004A/B is calculated using the volume transferred in LVP21 and the volume of condensate received from DEP-EVAP-00001.

$$V_{DEPVSL4,annual} = V_{LVP21,annual} + V_{evap,feed} * 3.785 \frac{L}{gal} * (1 - \frac{1}{CF}) * 525600 \frac{min}{yr} \quad \text{Equation 55}$$

Where:

- $V_{DEPVSL4,annual}$ = Annual volume received in DEP-VSL-00004A/B, in L
- $V_{LVP21,annual}$ = Annual volume transferred in LVP21, in L (Equation 53)
- $V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm (Assumption 6.1.7)
- CF = Evaporator volumetric concentration factor (Assumption 6.1.17)

The concentration of NH₃ in DEP-VSL-00004A/B and DEP-VSL-00005A/B is then calculated using the results from Equation 54 and Equation 55.

$$c_{NH_3} = \frac{m_{LVP21,NH_3}}{V_{DEPVSL4,annual}} \quad \text{Equation 56}$$

Where:

- c_{NH_3} = Concentration of NH₃ in DEP-VSL-00004A/B and DEP-VSL-00005A/B, in g/L (Assumption 6.1.18)
- m_{LVP21,NH_3} = Annual mass of NH₃ in LVP21, in g (Equation 54)
- $V_{DEPVSL4,annual}$ = Annual volume received in DEP-VSL-00004A/B, in L (Equation 55)

Next, use Equation 44 (defined in Section 5.2.4.1.1) to determine the mole fraction of NH₃ in the vapor phase using Henry's Law.

$$y_{NH_3} = \frac{k'_{H,NH_3} * \frac{c_{NH_3}}{MW_{NH_3}} * \frac{1000 \text{ liters}}{m^3}}{P} \quad \text{Equation 44}$$

Where:

- y_{NH_3} = Mole fraction of NH₃ in the vapor phase
- k'_{H,NH_3} = Henry's Law constant for NH₃, in atm*m³/mol (Input 2.18)
- c_{NH_3} = Concentration of NH₃ in DEP-VSL-00004A/B, in g/L (Equation 56)
- MW_{NH_3} = Molecular weight of NH₃, in g/mol (Input 2.9)
- P = Vessel operating pressure, in atm (Assumption 6.1.10)

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The mass flowrate of NH₃ in the vessel vent streams from DEP-VSL-00004A/B and DEP-VSL-00005A/B is calculated using Equation 45 (defined in Section 5.2.4.1.1).

$$\bar{m}_{vapor,vent,NH_3} = \frac{\bar{m}_{vent} * \frac{453.5924 \text{ g} * \text{hour}}{\text{lb}} * \frac{\text{hour}}{3600 \text{ sec}}}{MW_{air}} * Y_{NH_3} * MW_{NH_3} \quad \text{Equation 45}$$

Where:

$\bar{m}_{vapor,vent,NH_3}$ = Vapor phase mass flow rate of NH₃ in vessel vent streams from DEP-VSL-00004A/B and DEP-VSL-00005A/B, in g/sec

\bar{m}_{vent} = Mass flowrate of the vessel vent streams from DEP-VSL-00004A/B and DEP-VSL-00005A/B, in lb/hr (Assumption 6.1.19)

MW_{air} = Average molecular weight of air, in g/mol (Input 2.8)

Y_{NH_3} = Mole fraction of NH₃ in the vapor phase (Equation 44)

MW_{NH_3} = Molecular weight of NH₃, in g/mol (Input 2.9)

The total unabated emissions of NH₃ are then calculated by combining the unabated emissions for NH₃ received in the feed line flush calculated using the method from Section 5.2.1.5, Equation 30 and the value for $\bar{m}_{vapor,vent,i}$ calculated using Equation 45.

$$\bar{m}_{NH_3,tot,unabated} = \bar{m}_{vapor,vent,NH_3} + \bar{m}_{NH_3,flush,unabated} \quad \text{Equation 57}$$

Where:

$\bar{m}_{NH_3,tot,unabated}$ = Total unabated emissions of NH₃, in g/sec

$\bar{m}_{vapor,vent,NH_3}$ = Vapor phase mass flow rate of NH₃ in vessel vent streams from DEP-VSL-00004A/B and DEP-VSL-00005A/B, g/sec (Equation 45)

$\bar{m}_{NH_3,flush,unabated}$ = Unabated vapor phase emissions of NH₃ in feed line flush, in g/sec (Equation 30)

For vapor phase COPCs with an F_v of 1, the DF is 1 through both the primary and secondary HEPA filter (Assumption 6.2.10). Therefore there is no emissions abatement provided by the HEPA filters for NH₃.

5.3.1.3.3 Dimethyl Mercury

Dimethyl Mercury [(CH₃)₂Hg] has the potential to form in WTP waste streams due to the reaction between mercury and organic species (Ref. 9.15, Section 4.1).

5.3.1.3.3.1 Mercury Concentrations

In order to calculate the amount of dimethyl mercury generated in each DEP process vessel, the maximum mercury concentrations in each vessel are needed.

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DEP-VSL-00001

The Hg concentration in DEP-VSL-00001 can be calculated using the following equation.

$$C_{Hg,flush} = C_{Hg,feed} * \frac{V_{residual\ feed}}{V_{flush} * 3.785 \frac{L}{gal}} \quad \text{Equation 58}$$

Where:

- $C_{Hg,flush}$ = Concentration of Hg in feed line flush to DEP-VSL-00001, in g/L
- $C_{Hg,feed}$ = Maximum feed vector batch concentration of Hg, in g/L (Equation 11)
- $V_{residual\ feed}$ = Volume of residual feed in a LAW feed line flush, in L (Equation 16)
- V_{flush} = Total volume of LAW feed line flush, in gal (Input 2.4, Assumption 6.1.3)

Note that if the ICD-30 limit for Hg is used in Section 5.3.1.2.1 for the emission of Hg in the particle phase, then $C_{Hg,feed}$ will be the Hg feed concentration at the ICD-30 limit.

DEP-VSL-00002

The Hg concentration in DEP-VSL-00002 is assumed to be the same as in DEP-VSL-00001 (Assumption 6.1.20).

DEP-EVAP-00001 & DEP-VSL-00003A/B/C

The Hg concentration in DEP-EVAP-00001 and DEP-VSL-00003A/B/C is determined based on the following equation:

$$C_{Hg,conc} = \frac{\text{mass rate of Hg in Evap. Conc.}}{\text{volume rate of Evap. Conc.}} = \frac{C_{Hg,flush} * V_{evap,feed} * (1 - MDR_{Evap,Hg})}{V_{evap,feed} * (\frac{1}{CF})} \quad \text{Equation 59}$$

Where:

- $C_{Hg,conc}$ = Concentration of Hg in evaporator concentrate, in g/L
- $C_{Hg,flush}$ = Concentration of Hg in feed line flush to DEP-VSL-00001, in g/L (Equation 58)
- $V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm (Assumption 6.1.7)
- $MDR_{Evap,Hg}$ = Mass distribution ratio of Hg in evaporator (Assumption 6.1.13)
- CF = Evaporator volumetric concentration factor (Assumption 6.1.17)

DEP-VSL-00004A/B & DEP-VSL-00005A/B

The Hg concentration in DEP-VSL-00004A/B and DEP-VSL-00005A/B is assumed to be at the concentration of Hg in the evaporator condensate (Assumption 6.1.21), which is determined based on the following equation:

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$$c_{Hg,cond} = \frac{\text{mass rate of Hg in Evap. Cond.}}{\text{volume rate of Evap. Cond.}} = \frac{c_{Hg,flush} * V_{evap,feed} * MDR_{Evap,Hg}}{V_{evap,feed} * (1 - \frac{1}{CF})} \quad \text{Equation 60}$$

Where:

- $c_{Hg,cond}$ = Concentration of Hg in evaporator condensate, in g/L
- $c_{Hg,flush}$ = Concentration of Hg in feed line flush to DEP-VSL-00001, in g/L (Equation 58)
- $V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm (Assumption 6.1.7)
- $MDR_{Evap,Hg}$ = Mass distribution ratio of Hg in evaporator (Assumption 6.1.13)
- CF = Evaporator volumetric concentration factor (Assumption 6.1.17)

5.3.1.3.3.2 Vessel Operating Temperatures

Vessel operating temperatures are used in the calculation of dimethyl mercury formation rates. The nominal temperatures established in DEP process calculations will be used as the operating temperatures for this calculation (Assumptions 6.1.22 through 6.1.27).

5.3.1.3.3.3 Vessel Residence Time

Vessel residence times are determined based on the vessel batch cycle times established in the DEP batch sizing calculation (Ref. 9.10) (Assumption 6.1.28). The maximum vessel residence time represents the amount of time between cycle start times for the vessel. For single vessels, the maximum residence time equals the cycle time. For paired vessels (i.e. DEP-VSL-00004A/B and DEP-VSL-00005A/B), the maximum residence time is the cycle time times two, since one of these vessels will be filled during the first cycle time and then drained during the second cycle time while the other vessel is being filled. For triple vessels (i.e. DEP-VSL-00003A/B/C), the maximum residence time is the cycle time times three. One vessel will be filled during the first cycle time, held for sampling during the second cycle time, and then drained during the third cycle time.

$$RT_j = CT_j * N_j \quad \text{Equation 61}$$

Where:

- RT_j = Residence time for vessel j , in hr
- CT_j = Vessel j batch cycle time, in hr (Assumption 6.1.28)
- N_j = Quantity of vessel j (e.g. $N_{DEP-VSL-4} = 2$)

The DEP evaporator is not included in the batch sizing calculation, so its residence time is based on the time to fill and drain the evaporator recirculation loop operating volume (Assumption 6.1.29) at the evaporator feed rate (Assumption 6.1.7).

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$$RT_{evap} = \frac{V_{evap,recirc}}{V_{evap,feed}} * 2 * \frac{1 \text{ hr}}{60 \text{ min}} \quad \text{Equation 62}$$

Where:

RT_{evap} = Residence time for evaporator, in hr

$V_{evap,recirc}$ = Volume of DEP evaporator recirculation loop, in gal (Assumption 6.1.29)

$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm (Assumption 6.1.7)

5.3.1.3.3.4 Rate of Dimethyl Mercury Formation

The rate constant for the formation of dimethyl mercury from mercury or its compounds in caustic salt solutions with organics can be estimated based on the following equation (Assumption 6.2.24):

$$k_j = e^{-\left(\frac{5886.9}{T_j} + 2.7037\right)} \quad \text{Equation 63}$$

Where:

k_j = Rate constant for vessel j , in s^{-1}

T_j = Vessel j Nominal Temperature, in K (Section 5.3.1.3.3.2)

The maximum concentration of dimethyl mercury reached in each vessel is then calculated:

$$c_{DMHg,j} = k_j * c_{Hg,j} * RT_j * \frac{3600 \text{ sec}}{\text{hr}} \quad \text{Equation 64}$$

Where:

$c_{DMHg,j}$ = Concentration of dimethyl mercury in vessel j , in g/L

k_j = Rate constant for vessel j , in s^{-1} (Equation 63)

$c_{Hg,j}$ = Concentration of Hg in vessel j , in g/L (Section 5.3.1.3.3.1)

RT_j = Vessel j residence time, in hr (Section 5.3.1.3.3.3)

As a bounding assumption, all dimethyl mercury formed in a vessel is assumed to be emitted from that vessel (Assumption 6.2.23). The annual vessel throughput for each DEP vessel is calculated using the vessel batch volumes, quantities, and residence times.

$$\bar{V}_j = V_{batch,j} * N_j * 3.785 \frac{\text{L}}{\text{gal}} * \frac{8760 \frac{\text{hr}}{\text{yr}}}{RT_j} \quad \text{Equation 65}$$

Where:

\bar{V}_j = Annual vessel j throughput, in L

$V_{batch,j}$ = Vessel j batch volume, in gal (Assumption 6.1.30)

N_j = Quantity of vessel j (e.g. $N_{DEP-VSL-4} = 2$)

RT_j = Vessel j residence time, in hr (Section 5.3.1.3.3.3)

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Note, there is not an established batch volume for DEP-EVAP-00001 in Ref. 9.10. The throughput of DEP-EVAP-00001 is represented by the evaporator concentrate stream that is transferred to DEP-VSL-00003A/B/C, therefore the throughput of DEP-EVAP-00001 is equal to DEP-VSL-00003A/B/C.

The unabated vapor phase emissions of dimethyl mercury from each DEP vessel is calculated using the results from Equation 64 and Equation 65, and then summed to give a total unabated vapor emission estimate for dimethyl mercury.

$$\bar{m}_{DMHg,unabated,j} = c_{DMHg,j} * \bar{V}_j * 3.1536E7 \frac{sec}{yr} \quad \text{Equation 66}$$

Where:

$$\begin{aligned} \bar{m}_{DMHg,unabated,j} &= \text{Unabated vapor phase emissions of dimethyl mercury from vessel } j, \text{ in g/sec} \\ c_{DMHg,j} &= \text{Concentration of dimethyl mercury in vessel } j, \text{ in g/L (Equation 64)} \\ \bar{V}_j &= \text{Annual vessel } j \text{ throughput, in L (Equation 65)} \end{aligned}$$

$$\bar{m}_{DMHg,unabated,tot} = \sum \bar{m}_{DMHg,unabated,j} \quad \text{Equation 67}$$

Where:

$$\begin{aligned} \bar{m}_{DMHg,unabated,tot} &= \text{Total unabated vapor phase emissions of dimethyl mercury from vessel } j, \text{ in g/sec} \\ \bar{m}_{DMHg,unabated,j} &= \text{Unabated vapor phase emissions of dimethyl mercury from vessel } j, \text{ in g/sec} \\ &\quad \text{(Equation 66)} \end{aligned}$$

For vapor phase COPCs with an F_v of 1, the DF is 1 through both the primary and secondary HEPA filter (Assumption 6.2.10). Therefore, there is no emissions abatement provided by the HEPA filters for dimethyl mercury.

5.3.2 Stack Inorganic COPC Emissions

In general, stack inorganics are not expected to be emitted from the DEP system in significant quantities. The justification for this will be discussed in Section 7.3.2.

Particulate matter is considered a stack inorganic COPC (Ref. 9.1), therefore the total particulate emissions summed from the results for particulate emissions of radionuclides, feed organics, PICs, and feed inorganics will be reported as the emissions estimate for particulate matter.

5.3.3 Inorganic COPC Summary and Comparison to De Minimis Emissions Limits

The results for unabated and abated inorganic COPC emissions are compiled in a summary table (Table 8-6). The unabated inorganic COPC emissions are compared to de minimis emissions limits for TAPs established in WAC 173-460-150 (Input 2.13), using the same method established for organic COPCs in Section 5.2.4.

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6 Assumptions

6.1 Assumptions Requiring Verification

6.1.1 Mass Fractions of COPCs Released by Entrainment

Assumption

For the calculation of COPCs emission through entrainment, the mass fractions of COPCs with F_v values less than 1, meaning the COPC will at least partially be emitted through entrainment, are assumed to remain constant throughout the DEP system at the maximum feed vector batch mass fraction, x_i . For PICs, which are not present in the feed vector, the mass fractions of PIC COPCs with F_v values less than 1 are assumed to remain constant throughout the DEP system at the mass fraction in Stream RLD21, $x_{RLD21,i}$.

Verification

It is conservative and bounding to assume the mass fractions of these COPCs do not decrease from the maximum expected feed value throughout the DEP system. This is a simplifying assumption to help calculate conservative values for the entrainment of COPCs. This assumption for mass fractions will be verified by DFLAW-specific emissions estimate model runs using the APPS model, which will provide mass fractions of the COPCs in each of the DEP streams.

6.1.2 Dilution Factor of Feed Line Flush to DEP-VSL-00001

Assumption

The dilution factor of the feed line flush to DEP-VSL-00001 is assumed to be $\frac{1}{30}$ (i.e. one thirtieth of the flush to DEP-VSL-00001 is assumed to be residual LAW feed and the remainder is flush water).

Verification

The dilution factor of $\frac{1}{30}$ will be verified by confirmed isometric drawings providing the length and volume for this dead legged section of piping.

The flush volume is 1500 gallons based on Input 2.4 and Assumption 6.1.3, so a dilution factor of $\frac{1}{30}$ means that there is 50 gallons (6.68 ft³) of residual feed flushed to DEP-VSL-00001 along with the flush water. Based on the 3.068 inch (0.2557 ft) inner diameter of the transfer line (Input 2.12), the length of pipe represented by the 50 gallon residual volume can be calculated using the following equation (Ref. 10.3, Page A-9):

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$$V_{pipe} = \frac{\pi * D^2}{4} * L$$

Equation 68

Where:

V_{pipe} = volume of pipe, in ft³

π = 3.14

D = inner diameter of pipe, in ft

L = length of pipe, in ft

Solving Equation 68 for L gives a pipe length of 130 feet, meaning that the volume of residual feed flushed to DEP-VSL-00001 represents a 130 ft length of the feed transfer line filled with residual feed being flushed to DEP-VSL-00001. This length of pipe flushed to DEP-VSL-00001 corresponds to the dead leg between the main feed transfer line to LCP-VSL-00001/2 and the entrance to DEP-VSL-00001. This length of pipe based on the assumed dilution factor is conservative for the expected length of the dead leg. In addition, very little residual feed is expected to be flushed from the main feed line to DEP-VSL-00001 based on this statement from ICD-30 (Ref. 9.3, Section 2.6.2):

When the flush water first reaches the CRV [Concentrate Receipt Vessel], the WTP Contractor will align valves to stop delivery to the CRV and send flush water to the low point drain vessel in the WTP effluent management facility (EMF). When the flow of flush water is stopped, the Tank Operations Contractor isolates the transfer pipeline from connected equipment, and the WTP Contractor drains the contents of the pipeline to the low point drain vessel.

Therefore the dilution factor of $\frac{1}{30}$ is considered a conservative value for the approximation of the amount of residual feed flushed to DEP-VSL-00001.

6.1.3 Frequency of Feed Line Flush to DEP-VSL-00001

Assumption

The flush frequency from LAWPS to DEP-VSL-00001 is 18.8 hours per 24590-BOF-MVC-DEP-00009 (Ref. 9.10, Section 7.1.2).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00009 (Ref. 9.10).

6.1.4 Mass Flowrate of the DVP System Exhaust Streams

Assumption

The vessel ventilation streams are collected in a common exhaust header (noted as Stream DEP15 in Ref. 9.7) before passing through the preheater, two-stage HEPA filters, and finally through an exhaust fan to discharge the air out of the EMF stack. The total mass flow rate of this exhaust header is 578 lb/hr according to calculation 24590-BOF-M6C-DVP-00001 (Ref. 9.11, Attachment D). Line number DVP-GV-00010/00013 in Ref. 9.11, Attachment D represents the common exhaust header, and the line

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numbers shown below DVP-GV-00010/00013 represent the DVP lines leading to the exhaust from the EMF stack. These lines in Ref. 9.11, Attachment D all have a mass flow rate of 578 lb/hr.

Line number DVP-GV-00005 in Ref. 9.11, Attachment D represents the evaporator vent stream coming off of DEP-COND-00003 with a mass flow rate of 50 lb/hr.

For the calculation of NH₃ emissions in Section 5.3.1.3.2, only the mass flowrates of the DEP-VSL-00004A/B and DEP-VSL-00005A/B vessel vent streams are needed. In Ref. 9.11, Attachment B, the line number DVP-GV-00004 represents the vessel vent header for these 4 vessels. Line number DVP-GV-00004 has a mass flowrate of 235 lb/hr in Ref. 9.11, Attachment D.

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-M6C-DVP-00001 (Ref. 9.11).

6.1.5 ¹⁴C or ³H Only Transferred to the DEP System in the Feed Line Flush

Assumption

It is assumed that ¹⁴C and ³H are only transferred to the DEP System in the feed line flush stream received in DEP-VSL-00001.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model. This is a simplifying assumption for the purpose of establishing the amount of ¹⁴C and ³H received in, and subsequently emitted by, the DEP system annually (Assumption 6.2.4). The only other waste streams entering the DEP system that may contain significant amounts of radionuclides are the SBS condensate stream (RLD21) and the Plant Wash Vessel effluent (RLD27) (Ref. 9.5). However, this assumption, combined with the conservatism in the other assumptions that support the calculation of the amounts of ¹⁴C and ³H flushed to DEP-VSL-00001 (See Assumptions 6.1.2, 6.2.1, and 6.2.5), is expected to bound the amounts of ¹⁴C and ³H expected to be received, under steady-state conditions, from all the expected input streams (Feed line flush, RLD21, and RLD27).

6.1.6 Organic COPC Physical Properties

Assumption

Physical properties of organic COPCs extracted from Ref. 9.15, Attachment A are used in this calculation. This includes F_v values, Henry's Law constants, Feed/PIC COPCs, and molecular weights.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model and the physical properties included in the APPS model.

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6.1.7 DEP Evaporator Feed Volumetric Flowrate

Assumption

The volumetric flowrate of the feed stream from the Evaporator Feed Vessel to the Evaporator is assumed to be 10 gpm. This value is based on the design feed rate for the Cesium Nitric Acid Recovery Process system (CNP) evaporator (Ref. 9.16, Section 6.1.1). Detailed design on the DEP evaporator system is ongoing, but the design up to this point has used the CNP evaporator equipment design as a basis (See Ref. 9.17, Section 3).

Verification

This assumption will be verified by the acceptance of a Code 1 vendor mass and energy balance calculation for the DEP evaporator system.

6.1.8 DEP Evaporator Overheads Stream Volumetric Flowrate

Assumption

The nominal volumetric flowrate of the DEP evaporator overheads stream is 9.5 gpm (Ref. 9.17, Section 7.2). This represents 9 gpm of feed evaporated and a 0.5 gpm demister spray stream (recycled from the condensate).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MEC-DEP-00001 (Ref. 9.17).

6.1.9 DEP Evaporator Nominal Operating Temperature and Pressure

Assumption

The nominal operating temperature and pressure of the DEP evaporator are 1.45 psia (0.0987 atm) and 116°F (46.7°C), respectively (Ref. 9.17, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MEC-DEP-00001 (Ref. 9.17).

6.1.10 DEP System Vessel Pressure

Assumption

The pressure in the main DEP system vessels is 14.14 psia (0.9622 atm). This is the minimum pressure of the vessel vent inlet for DEP vessels calculated in Ref. 9.11, Section 7.1.

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-M6C-DVP-00001 (Ref. 9.11).

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6.1.11 Concentrations of Feed Organic COPCs Used in Section 5.2.4.1

Assumption

For the Henry's Law analysis in Section 5.2.4.1, the concentrations of the feed organic COPCs evaluated are assumed to remain constant at the concentration in the feed line flush stream, $c_{i,flush}$ (Equation 39).

Verification

This is a simplifying assumption to help calculate vapor phase emissions using Henry's Law. This assumption for COPC concentrations will be verified by DFLAW-specific emissions estimate model runs using the APPS model, which will provide concentrations of COPCs in each of the DEP streams.

6.1.12 Total Vessel Vent System Flowrate Used in Section 5.2.4.1.1

Assumption

The total vessel vent system flowrate used in Section 5.2.4.1.1 to calculate vessel vent emissions based on Henry's Law from the main DEP vessels, excluding the DEP evaporator, is assumed to be the total vessel vent exhaust flowrate from Assumption 6.1.4. This assumption is conservative because this flowrate includes the vent stream from the DEP evaporator system (which is evaluated separately).

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.13 DEP Evaporator/Condenser MDRs

Assumption

The DEP evaporator/condenser MDRs are assumed to be the same as the FEP/TLP evaporator/condenser MDRs which are determined in 24590-WTP-M4C-V37T-00011, Rev. 0 - *FEP and TLP Evaporator and Condensers Decontamination Factor Calculation* (Ref. 9.19, Section 8, Tables 2 and 3).

Verification

The MDRs established in Ref. 9.19 for the FEP/TLP evaporators/condensers are based on operational data from the 242-A evaporator at the Tank Farms. The applicability of using the 242-A evaporator operational data is justified based on a comparison of the thermodynamic, configurational, and geometric similarities with the FEP/TLP evaporator designs (Ref. 9.19, Section 6.1). This assumption for DEP evaporator/condenser MDRs will be verified when the DEP evaporator design progresses to a point that a comparison can be made with the FEP/TLP evaporators.

6.1.14 Condenser MDRs for Feed Organic COPCs Evaluated in Section 5.2.4.1.2

Assumption

The primary and inter-condenser MDRs for VOCs (based on benzene) calculated in Ref. 9.19 (3.27E-3 and 1.06E-1, respectively) are assumed to apply to all Feed Organic COPCs evaluated in Section 5.2.4.1.2.

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Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.15 LAW Melter Feed Maximum TOC during DFLAW Operation

Assumption

The maximum TOC value for the LAW melter feed stream (LFP04) during DFLAW operations is assumed to be represented by the maximum TOC value for LFP04 calculated in the current PIBOD (Attachment F, Table F-1). Note: as shown in Attachment F, the maximum PIBOD value for TOC of 15.29 kg/hr will be rounded up to 20 kg/hr for use in this calculation.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.16 Mass Fraction of NH₃ in Stream LVP21 during DFLAW Operations

Assumption

The maximum mass fraction of NH₃ in the caustic scrubber effluent stream (LVP21) during DFLAW operations is assumed to be represented by the maximum value for LVP21 calculated in the current PIBOD (Attachment F, Table F-2). Note: as shown in Attachment F, the maximum PIBOD value for the mass fraction of NH₃ (0.0512) will be rounded up to 0.06 for use in this calculation.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.17 DEP Evaporator Volumetric Concentration Factor

Assumption:

Overconcentration of the evaporator concentrate will result in the formation of insoluble solids as chemical species reach their saturation point and precipitate from solution.

Initial testing at Savannah River National Laboratory demonstrated that a concentration factor of 17X at alkaline pH was possible without significant insoluble solids precipitation (Ref. 10.10, Page vii).

In order to mitigate the precipitation of solids in the evaporator, this calculation will use an assumed nominal concentration factor of 10X (meaning the volumetric flowrate of the evaporator feed stream is 10 times greater than the volumetric flowrate of the evaporator concentrate stream).

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Verification:

The concentration factor assumption will be verified as the detailed design of the DEP-EVAP-00001 progresses and bounding limits on the evaporator operation are established. The DFLAW-specific mass balance calculation (to be developed) will establish the basis for determining the steady-state properties of the evaporator concentrate based on operational constraints.

NOTE: This maximum concentration factor based on limiting formation of solids in the evaporator is not provided in this calculation to establish an operational constraint on the evaporator. The solubility of species in the waste is one factor that limits the concentration factor in the evaporator. Other factors include the concentrations of chloride and certain radionuclides. It is outside the scope of this calculation to develop a model for predicting the concentration limit for the DEP evaporator based on these factors.

6.1.18 Concentration of NH₃ in DEP-VSL-00004A/B and DEP-VSL-00005A/B

Assumption

The concentration of NH₃ in DEP-VSL-00004A/B and DEP-VSL-00005A/B is assumed to remain constant at the value calculated using Equation 56 (i.e. the concentration of NH₃ in DEP-VSL-00004A/B due to the receipt of stream LVP21 is assumed to remain the same when the contents of DEP-VSL-00004A/B are transferred to DEP-VSL-00005A/B).

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.19 Mass Flowrate of DEP-VSL-00004A/B and DEP-VSL-00005A/B Vessel Vent Header

Assumption

For the calculation of NH₃ emissions in Section 5.3.1.3.2, only the mass flowrates of the DEP-VSL-00004A/B and DEP-VSL-00005A/B vessel vent streams are needed. In Ref. 9.11, Attachment B, the line number DVP-GV-00004 represents the vessel vent header for these 4 vessels. Line number DVP-GV-00004 has a mass flowrate of 235 lb/hr (Ref. 9.11, Attachment D).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-M6C-DVP-00001 (Ref. 9.11).

6.1.20 Concentration of Hg in DEP-VSL-00002 for Dimethyl Mercury Formation

Assumption

For the calculation of dimethyl mercury formation in Section 5.3.1.3.3, the concentration of Hg in DEP-VSL-00002 is assumed to be the same as the Hg concentration in DEP-VSL-00001. As mentioned in Assumption 6.1.33, mercury has the potential to accumulate in the recycle from the DEP system to LAW during DFLAW operations, however developing a detailed model of this accumulation is outside the

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scope of this emissions estimate. Also, the PIBOD shows that there is no Hg in stream RLD21 due to a DF of 1 being applied in the SBS for mercury (Attachment F, Table F-3).

Therefore, the amount of Hg captured in the SBS condensate and transferred to the DEP system in stream RLD21 is not modeled in this emissions estimate and the concentration in DEP-VSL-00001 is assumed to represent the concentration in DEP-VSL-00002.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.21 Concentration of Hg in DEP-VSL-00004A/B and DEP-VSL-00005A/B for Dimethyl Mercury Formation

Assumption

For the calculation of dimethyl mercury formation in Section 5.3.1.3.3, the concentration of Hg in DEP-VSL-00004A/B and DEP-VSL-00005A/B is assumed to be the same as the Hg concentration in the evaporator condensate. This is a conservative assumption because the caustic scrubber effluent stream (LVP21) should have a negligible amount of Hg and therefore dilute the Hg concentration in DEP-VSL-00004A/B and DEP-VSL-00005A/B.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.22 DEP-VSL-00001 Nominal Temperature

Assumption

The nominal temperature of DEP-VSL-00001 is 67°F (Ref. 9.27, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00011 (Ref. 9.27).

6.1.23 DEP-VSL-00002 Nominal Temperature

Assumption

The nominal temperature of DEP-VSL-00001 is 124°F (Ref. 9.31, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00003.

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6.1.24 DEP-EVAP-00001 Nominal Temperature

Assumption

The nominal temperature of DEP-EVAP-00001 is 116°F (Ref. 9.17, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MEC-DEP-00001.

6.1.25 DEP-VSL-00003A/B/C Nominal Temperature

Assumption

The nominal temperature of DEP-VSL-00003A/B/C is 116°F (Ref. 9.32, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00010.

6.1.26 DEP-VSL-00004A/B Nominal Temperature

Assumption

The nominal temperature of DEP-VSL-00004A/B is 115°F (Ref. 9.33, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00007.

6.1.27 DEP-VSL-00005A/B Nominal Temperature

Assumption

The nominal temperature of DEP-VSL-00005A/B is 115°F (Ref. 9.34, Section 8).

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00008.

6.1.28 DEP Vessel Cycle Times

Assumption

The following vessel batch cycle times for DEP vessels are provided based on the vessel storage volumes established in Ref. 9.10, Section 8:

Vessel	Cycle Time
DEP-VSL-00001	48 hours
DEP-VSL-00002	48 hours
DEP-VSL-00003A/B/C	120 hours (5 days)
DEP-VSL-00004A/B	24 hours
DEP-VSL-00005A/B	96 hours (4 days)

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Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00009 (Ref. 9.10).

6.1.29 DEP-EVAP-00001 Recirculation Loop Operating Volume

Assumption

The DEP evaporator vessel, DEP-EVAP-00001 is assumed to have the same recirculation loop volume as the CNP evaporator. The CNP evaporator has a maximum recirculation loop volume of 2721 gallons (Ref. 9.28, Section 8.1)

Verification

This assumption will be verified by the acceptance of a Code 1 vendor design drawings for the DEP evaporator system.

6.1.30 DEP Vessel Batch Volumes

Assumption

The following vessel batch volumes for DEP vessels are provided in Ref. 9.10, Section 8:

Vessel	Batch Volume (gal)*
DEP-VSL-00001	6,300
DEP-VSL-00002	28,800
DEP-VSL-00003A/B/C	7,600
DEP-VSL-00004A/B	22,300
DEP-VSL-00005A/B	89,200

*The batch volumes are per vessel

Verification

This assumption will be verified by the confirmation of calculation 24590-BOF-MVC-DEP-00009 (Ref. 9.10).

6.1.31 Stack Inorganic COPC Emissions

Assumption

Stack inorganic COPCs, except for methyl mercury and particulate matter, are gases or acids that are mainly produced during chemical reactions or thermal decomposition. These COPCs are:

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Nitrogen dioxide
Carbon dioxide
Carbon monoxide
Ozone
Sulfur dioxide
Hydrogen chloride
Hydrogen Fluoride
Fluorine gas
Chlorine gas

The main source for these COPCs at WTP is the LAW and HLW melters. For example, in the existing WTP emissions estimate (Ref. 9.14, Table 18) the only streams with emissions of NO₂, CO, SO₂, HCl, and HF are the LAW and HLW offgas streams. Note that CO₂, O₃, F₂, and Cl₂ were not included in the existing WTP emissions estimate. It is assumed that there will not be the necessary thermal or kinetic conditions in the DEP system to produce significant amounts of the stack inorganic COPCs.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model

6.1.32 Mercury Speciation in the DEP System

Assumption

A detailed analysis of the speciation of mercury throughout the DEP system is outside the scope of this emissions estimate. As an assumption, mercury received in the DEP system is assumed to be a non-volatile form (HgO) and emitted through entrainment. This assumption will be used to estimate emissions of mercury compounds, except for dimethyl mercury which is estimated separately.

The potential inlet streams to the DEP system containing mercury are the SBS condensate stream (RLD21) and the feed line flush to DEP-VSL-00001. These two streams are the main process inlet streams to the DEP system. Trace amounts of mercury may be present in other inlet streams to the DEP system, such as the Plant Wash Vessel effluent stream (RLD27) and the LAB sink drain effluent (RLD41), however any potential contribution from these streams is bounded by Assumption 6.1.33.

Gaseous mercury in the melter offgas is either absorbed in the SBS as aqueous HgCl₂ or passed through as elemental Hg. The fraction captured as HgCl₂ in the SBS versus passing through as Hg is dependent on the Hg:Cl molar ratio in the melter feed. The aqueous mercury in the SBS stream is then converted to hydrated mercuric oxide (HgO·H₂O(s)) when the stream is neutralized (Ref. 9.15, Section 4).

Mercury speciation in the Tank Farms is expected to be mainly HgO, as sampling has shown that mercury in the tank supernate is negligible and most is associated with the sludge and saltcake (Ref. 9.29, Section 7.2.2).

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

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6.1.33 Mass Fraction of Mercury for Particle Emissions

Assumption

For the calculation of emissions of Hg due to entrainment, the mass fraction of Hg is assumed to remain constant throughout the DEP system at the maximum feed vector batch mass fraction, x_{Hg} , or the ICD-30 feed limit mass fraction, $x_{Hg,ICD30}$, depending on which is greater. This is a similar assumption to the one used for other COPCs emitted due to entrainment (Assumption 6.1.1).

Mercury has the potential to accumulate in the recycle stream from the DEP system back to LAW during DFLAW operations since mercury is not vitrified (DF of 1 in the LAW melter per Ref. 9.14, Table 14), is captured in the SBS (Assumption 6.1.32), and the non-volatile mercury species are concentrated in the DEP evaporator. However, a detailed analysis of the accumulation of mercury in the DEP system is outside the scope of this emissions estimate. Applying the maximum feed mass fraction across the entire DEP system should still be conservative because some tanks will have very low concentrations of mercury (i.e. DEP-VSL-00001, DEP-VSL-00004A/B, and DEP-VSL-00005A/B), while others will see higher concentrations (i.e. DEP-VSL-00002, and DEP-EVAP-00001, and DEP-VSL-00003A/B/C).

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.34 Average Feed Vector Batch Volumes, Densities, and Masses in Equation 9 through Equation 11

Assumption

Average feed vector batch volumes, densities, and masses are used in Equation 9 through Equation 11 to calculate conservative values for maximum feed vector batch mass fractions, x_i , and concentrations, c_i . Dividing the maximum feed vector batch mass, m_i , by average values instead of maximum values for mass and volume provide conservative results for x_i and c_i , respectively.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.35 ³H Emissions

Assumption

The emissions of ³H from the DEP system are assumed to be controlled by the evaporator/condenser MDRs established in Ref. 9.19. Since ³H is assumed to be present as tritiated water (Assumption 6.2.7), the emissions of ³H will follow the emissions of water vapor. Some water vapor (and therefore ³H₂O) will be released through the the evaporator vent stream. The evaporator/condenser MDRs for ³H will be used to estimate the amount of ³H that is not condensed in the condensers and is emitted to the DVP exhaust system.

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Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.36 ³H Emissions Evaporator Feed Mass Flowrate

Assumption

The calculation for ³H emissions, using the evaporator/condenser MDRs, will use the value for $\bar{m}_{i,flush}$, calculated in Equation 17, as the evaporator feed mass flowrate, $\bar{m}_{i,feed}$.

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.1.37 Vapor Phase Feed Organic COPCs Only Transferred to the DEP System in the Feed Line Flush

Assumption

It is assumed that vapor phase feed organic COPCs are only transferred to the DEP System in the feed line flush stream received in DEP-VSL-00001. Feed organic COPCs received in LAW are processed through the melters. Any portion of the organic COPCs that is not vitrified or destroyed in the melter enters the melter offgas stream. The vapor phase organic COPCs have a DF of 1 in the SBS (Assumption 6.2.15) and will, therefore, not be transferred to the DEP system in the SBS condensate stream (RLD21). Trace amounts of organics may be present in other inlet streams to the DEP system, such as the Plant Wash Vessel effluent stream (RLD27) and the LAB sink drain effluent (RLD41), however, this assumption, combined with the conservatism in the other assumptions that support the calculation of the amount of feed organic COPCs flushed to DEP-VSL-00001 (See Assumptions 6.1.2, 6.2.1, and 6.2.5), is expected to provide an amount of feed organic COPCs that bounds the amount expected to be received under steady-state conditions that account for all the expected input streams (Feed line flush, RLD21, RLD27, and RLD41).

Verification

This assumption will be verified by DFLAW-specific emissions estimate model runs using the APPS model.

6.2 Assumptions Not Requiring Verification

6.2.1 Applicability of the Tank Farms Average Ratios

Assumption

The Tank Farms Average ratios provided in Ref. 9.2 represent the distribution of COPCs as they currently exists in the Tank Farms, based on best available estimates. It is assumed that the waste received at LAW during DFLAW operations has the same distribution represented by these ratios.

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Justification

This assumption is conservative because it does not account for any change in the composition of the waste between when the samples underlying the ratios were collected in the Tank Farms and when the waste is actually received at LAW. This means chemical interactions such as precipitation, dissolution, or volatilization of species within the waste before it is received at WTP are not accounted for. In addition, for radionuclides this means the tank farm ratios do not account for the radioactive decay that will occur between the time of the sampling and the delivery of the waste. It also does not account for any of the pretreatment processing that will occur in the LAWPS facility (such as ultrafiltration or cesium removal).

Note that, while this assumption is justified in order to provide a conservative estimate of radionuclide concentrations received for processing and emitted from the DEP process, the feed concentrations are checked against the ICD-30 feed acceptance criteria for individual radionuclide COPCs and adjusted as required per Section 5.1.1.1.

6.2.2 DFLAW Bounding Feed Vector

Assumption

DFLAW feed vectors are provided for nominal and bounding conditions in Ref. 9.2. The DFLAW Bounding Feed Vector is used in conjunction with the Tank Farms Average ratios to determine the amount of each COPC received in the feed to LAW during DFLAW operations.

Justification

The use of the DFLAW Bounding Feed Vector is bounding compared to using the DFLAW Nominal Feed Vector.

6.2.3 Entrainment Factor Applicability for Particulate Emissions from DEP Vessels

Assumption

The entrainment factor of $4E-5$ g entrained material / g air provided in Input 2.3 is assumed to apply to all DEP vessels for the estimation of particulate emissions. The applicability of the entrainment factor for the DEP evaporator is discussed separately in Assumption 6.2.30.

Justification

The entrainment factor for free-falling aqueous solution was chosen as a representative entrainment factor because the streams will enter DEP vessels above the fluid surface. The nominal entrainment factor of $4E-5$ is used because the fluid transfers will not occur continuously, therefore the free-fall condition will not occur continuously and the nominal value is more representative than the bounding value.

The nominal free-fall entrainment factor is also more conservative and representative for DEP vessels compared to other potential entrainment factors in DOE-HDBK-3010-94, such as the bounding entrainment factor of $4E-7$ for aerodynamic entrainment and resuspension of fluid that is “indoors, on heterogeneous surface (stainless steel, concrete), low airspeeds up to normal facility ventilation flow; outdoors, pool for low windspeeds.” (Ref. 10.2, Page 3-5) and the bounding entrainment factor of $3E-5$ for “heating of aqueous solution in flowing air without surface rupture of bubbles” (Ref. 10.2, Page 3-1).

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Additionally, 24590-CM-HC4-W000-00193-01-00001 - *Report - Aerosol Production in WTP Process Vessels - A Review of Recent Aerosol Testing* recommends an entrainment factor of 4E-5 for sparged vessels (Ref. 9.37 Page 8). The nominal free-fall entrainment factor of 4E-5 from Ref. 10.2 is therefore conservative since DEP vessels are non-sparged.

6.2.4 ¹⁴C Emissions

Assumption

It is assumed that all ¹⁴C received in the EMF is emitted as it is processed through the DEP system.

Justification

This assumption is bounding since actual emissions of ¹⁴C cannot exceed this value. The actual emissions are dependent on the vapor-liquid equilibrium of each COPC in each of the DEP vessels and evaporator/condensers and are likely to be less than the total release established with this assumption.

6.2.5 Availability of Transfers from LAWPS to LAW

Assumption

Feed transfers from the LAWPS to LAW are assumed to occur continuously without a break between transfers (i.e. a transfer begins immediately after the preceding one is finished).

Justification

This assumption is conservative and bounding, since it provides the maximum number of annual feed transfers and therefore the maximum number of flushes to the low point drain vessel (DEP-VSL-00001).

6.2.6 Carbon-14 Phase Property

Assumption

¹⁴C is assumed to be emitted as a vapor phase COPC.

Justification

This assumption is consistent with existing WTP emissions estimates, where ¹⁴C is assumed to exist as ¹⁴CO₂ in the waste (Ref. 9.4, Section 4.4) and is treated as a vapor phase (Ref. 9.12, Table 11-1). In order to check that this assumption is conservative, a sensitivity analysis was completed to compare the unabated and abated emissions of ¹⁴C using the methodology for particle emissions and vapor emissions (Attachment E). This analysis shows that assuming ¹⁴C is emitted as a vapor phase COPC is significantly more conservative than if it was emitted as a particle COPC.

6.2.7 Tritium Phase Property

Assumption

³H is assumed to be emitted as a vapor phase COPC.

Justification

This assumption is consistent with existing WTP emissions estimates, where ³H is assumed to exist as tritiated water (³H₂O) in the waste (Ref. 9.14, Table 12 Note b) and is treated as a vapor phase emission

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(Ref. 9.12, Table 11-1). In order to check that this assumption is conservative, a sensitivity analysis was completed to compare the unabated emissions of ^3H using the methodology for particle emissions and vapor emissions (Attachment E). This analysis shows that assuming ^3H is emitted as a vapor phase COPC is equivalent to if it was emitted as a particle COPC for unabated emissions and significantly more conservative for abated emissions.

6.2.8 Iodine-129 Phase Property

Assumption

^{129}I is assumed to be emitted as a particle COPC.

Justification

^{129}I is a volatile radionuclide with an F_v of 1 (Ref. 9.4, Section 4.4). Existing emissions estimates have treated ^{129}I as a vapor phase emission in the LAW and High Level Waste Facility (HLW), reflecting its presence as iodine gas in the melter offgas streams (Ref. 9.12, Table 11-1). However, in the Pretreatment Facility (PTF) there is no melter and the process streams are caustic. Under these conditions, essentially all ^{129}I will be in the form of iodide and iodate anions and ^{129}I emissions are expected to be in the form of aerosols (Ref. 9.9, Section 7.3.3). For that reason, ^{129}I has been treated as a particle emission in existing emissions estimates for the PTF (Ref. 9.12, Table 11-1). The DEP system process conditions will more closely resemble the PTF conditions just described (caustic process streams and no melter offgas), therefore ^{129}I will be treated as a particle/aerosol for emissions estimation.

6.2.9 Radionuclide Phase Properties (excluding ^{14}C , ^3H , and ^{129}I)

Assumption

All radionuclide COPCs, excluding ^{14}C , ^3H , and ^{129}I , are assumed to be emitted as particles.

Justification

This assumption is consistent with existing WTP emissions estimates, where all radionuclide COPCs, except or ^{14}C , ^3H , and ^{129}I , are considered metals and nonvolatile, and are assigned a vapor phase partitioning coefficient, F_v , of 0 (Ref. 9.4, Section 4.4) and treated as a particle for emissions (Ref. 9.12, Table 11-1).

6.2.10 HEPA Filter Decontamination Factors

Assumption

The following DFs are assumed for HEPA filters:

	1 st Stage HEPA Filter DF	2 nd Stage HEPA Filter DF
Particulate	2,000	100
Vapor-phase	1	1

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Justification

These HEPA DFs are used in existing WTP emissions estimates and permitting documents for the other WTP facilities (e.g. Ref. 9.12, Section 6.1 and Ref. 9.14, Tables 12, 14, and 15) and will be used in this calculation for consistency.

6.2.11 Duration of Release from DVP System to ACV Exhaust System

Assumption

The annual radionuclide emissions from the ACV Exhaust System are estimated assuming a 2 month release from the DVP system exhaust stream. Calculation 24590-HAC-50-00005 estimates annual C5V emissions based on a 2 month release from the pretreatment vessel vent system or 16 hour release from the LAW and HLW vitrification process (Ref. 9.13, Assumptions 6.4.1 and 6.4.2). For the ACV Exhaust System, a 2 month release is conservatively assumed, as it is the greater of the two release durations assumed in Ref. 9.13.

Justification

The 2 month release duration is considered conservative and bounding for any anticipated accidental release or release due to maintenance activities. Note that the EMF will not contain a maintenance shop so other than routine plant operations (i.e., HEPA change outs, valve/pump replacement), maintenance of removed equipment will be performed at an alternate location in the LAW Facility.

6.2.12 Distribution of Unspeciated Organic Carbon in Tank Farms Average Ratios

Assumption

The unspeciated organic carbon is assumed to be distributed proportionally to all of the organic compounds with Tank Farms Average ratios in Ref. 9.2, as an approximation to account for the unspeciated organic carbon in tank farm samples.

Justification

This assumption is justified because the scaled Tank Farms Average ratios calculated to account for the unspeciated organic carbon bound the unscaled Tank Farms Average ratios provided in Ref. 9.2.

6.2.13 DEP Evaporator Annual Uptime

Assumption

The annual uptime of the DEP evaporator is assumed to be 100% with a constant feed rate based on Assumption 6.1.7.

Justification

This assumption is bounding for determination of the annual throughput of the DEP evaporator based on volumetric feed rate from Assumption 6.1.7.

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6.2.14 Physical Properties of Evaporator Overheads Stream

Assumption

The evaporator overheads stream is assumed to have the physical properties of water.

Justification

This assumption is justified because the overheads stream leaving the Evaporator Separator Vessel will be water with trace elements. This assumption is established in order to calculate the density of the evaporator overheads stream using a correlation between temperature and density for water (Equation 47).

The main function of DEP-EVAP-00001 is to concentrate the SBS and WESP condensates transferred from the LAW offgas system (Section 3). In the baseline WTP configuration, these LAW offgas condensates are evaporated in the TLP evaporator system. The function of the TLP evaporator system in the TLP system description is stated as the following (Ref. 9.35, Section 2):

“The TLP system reduces the volume of treated LAW waste and LAW offgas condensate streams by evaporating water.”

The presence of trace volatile compounds will not significantly affect the density, justifying the assumption that the overheads stream has the physical properties of water.

6.2.15 SBS DF for Vapor Phase Organic COPCs

Assumption

The SBS DF for vapor phase organic COPCs is assumed to be 1 (Ref. 9.14, Table 16).

Verification

This is the SBS DF used for vapor phase organic COPCs in existing WTP emissions estimates for the other WTP facilities (Ref. 9.14, Tables 16) and will be used in this calculation for consistency.

6.2.16 Vapor Phase Feed Organic COPC Emissions

Assumption

It is assumed that the entire vapor fraction of each feed organic COPC received in DEP-VSL-00001 annually is emitted to the DEP vessel ventilation system as it is processed through the DEP system.

Justification

This assumption is bounding since actual vapor phase emissions of feed organic COPCs cannot exceed this value. The actual emissions are dependent on the vapor-liquid equilibrium of each COPC in each of the DEP vessels and evaporator/condensers and, in various cases, are likely to be less than the total release established with this assumption. This assumption is not applied to the subset of feed organic COPCs that are evaluated using a Henry's Law analysis in Section 5.2.4.1.

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6.2.17 PIC Generation Rate for Particle or Particle-Bound PIC COPCs without Generation Rates from Testing

Assumption

Particle or particle-bound PIC COPCs that do not have generation rates reported in Ref. 9.15, Table 3 are assigned a generation rate equal to the maximum generation rate for a particle or particle-bound PIC COPC that does have a generation rate reported in Ref. 9.15, Table 3.

Justification

This assumption is established in order to provide a conservative generation rate for PIC COPCs without reported generation rates.

6.2.18 Fraction of PIC COPC Particulate Captured in the SBS

Assumption

The entire fraction of each PIC COPC that exists as particulate, represented by $(1 - F_{v,i})$, is assumed to be captured in the SBS.

Justification

Organic COPCs with an F_v value less than 1 are partially present in off-gas streams as particulate. These organic COPCs have SBS DFs assigned (for example, Dibutylphosphate in Ref. 9.14, Table 16 has a particle phase SBS DF of 20). This means that some fraction of particulate is not captured in the SBS and continues in the off-gas stream. For estimation of particulate emissions of PIC COPCs from the DEP system, it is conservative and bounding to assume the entire particle fraction of a PIC COPC is captured in the SBS and subsequently transferred to the DEP system.

6.2.19 Transfer Frequency of RLD-VSL-00005

Assumption

The transfer frequency for RLD-VSL-00005 is once every 24 hours (Ref. 9.20, Section 6.1.1).

Justification

This transfer frequency is included in an assumption not requiring verification in Ref. 9.20, which is a confirmed calculation.

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6.2.20 Batch Volume of RLD-VSL-00005

Assumption

The batch volume of RLD-VSL-00005 is 10,700 gal without contingency (Ref. 9.20, Section 7.1). Note that the volume without contingency shown in Ref. 9.20 is 10,900 gallons. The 10,700 gallon volume used here reflects the reduction in volume contribution from RLD-VSL-00004 from 4,700 gallons to 4,500 gallons determined in calculation 24590-LAW-MVC-RLD-00009 as modified by ECCN 24590-LAW-MVE-RLD-00001 (Ref. 9.21, Section 7.1.2). Ref. 9.20 has not been updated to reflect this change to an input value.

Justification

For the purpose of this calculation, the batch volume of RLD-VSL-00005 is used without contingency for the following reasons:

- Reference 9.20 reports a batch volume of 16,000 gal which includes 40% contingency for conservatism. Excessive conservatism in batch volumes upstream of the DEP vessels creates over-design of the DEP evaporator and associated support systems. Over-design can result in unnecessary costs to the facility and process issues due to improper sizing of pipes and pumps.
- The batch volume value of RLD-VSL-00004, used for input in RLD-VSL-00005, is for the high humidity case, not the normal operations case. From Reference 9.21, the high humidity case creates more condensation thus having an increased batch volume of 4,500 gal vs. 3,100 gal for the normal operations case.

6.2.21 Phase Property of Feed Inorganic COPCs

Assumption

The offgas phase type of feed inorganic COPCs are determined using the F_v values calculated in CCN 129507 (Ref. 9.4, Table 2). Most feed inorganic COPCs have an F_v value of 0 and are emitted as particles, with the following exceptions:

- Bromide has an F_v value of 0.017. Ref. 9.4, Section 4 states that COPCs with an F_v value < 0.05 are considered particles. Therefore bromide will be evaluated using the same method as the other feed inorganic COPCs with F_v values of 0.
- Ammonia and cyanide have F_v values of 1 and are emitted as vapor.
- The phase type for mercury depends on its speciation and will be handled as a special case.

Justification

This assumption is consistent with existing WTP emissions estimates (Ref. 9.14, Table 3).

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6.2.22 Transfers from LVP-TK-00001 to DEP-VSL-00004A/B are Continuous

Assumption

Transfers from LVP-TK-00001 to DEP-VSL-00004A/B are assumed to occur continuously, with no break or downtime between transfers (i.e. as soon as a transfer ends, the next transfer begins).

Justification

This assumption is bounding since it provides the maximum number of transfers annually, and therefore the maximum volume transferred annually, from LVP-TK-00001 to DEP-VSL-00004A/B.

6.2.23 Dimethyl Mercury Emissions

Assumption

It is assumed that all dimethyl mercury formed in a DEP vessel is emitted from that vessel in the vapor phase.

Justification

This assumption is bounding since actual emissions of dimethyl mercury cannot exceed this value. The actual emissions are dependent on the vapor-liquid equilibrium of dimethyl mercury in each of the DEP vessels and evaporator/condensers and are likely to be less than the total release established with this assumption.

6.2.24 Dimethyl Mercury Formation Rate Constant

Assumption

The rate constant for the formation of dimethyl mercury from mercury or its compounds in caustic salt solutions in the presence of organics is assumed to be represented by the rate equation reported in CCN 160522 (Ref. 9.24, Figure 1).

$$k = e^{-\left(\frac{5886.9}{T} + 2.7037\right)}$$

Where:

k = Rate constant in a first order rate equation, in s^{-1}

T = Temperature, in K

Justification

This rate equation represents the best available information on the formation of dimethyl mercury in WTP waste streams. This rate equation forms the basis for the current WTP estimate of dimethyl mercury concentrations (Ref. 9.25, Section 5.5).

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6.2.25 Monomethyl Mercury Emissions

Assumption

Monomethyl mercury emissions are included with the total mercury emissions calculated according the methodology in Section 5.3.1.2.1.

Justification

Monomethyl mercury is nonvolatile and should be considered to exist mainly in the liquid phase within WTP waste streams (Ref. 9.24, Page 10). Therefore, monomethyl mercury emissions are include with the total emissions of mercury and not estimated separately like dimethyl mercury.

6.2.26 PIC Generation Rates

Assumption

The PIC generation rates detected in testing at the VSL are reported in Ref. 9.15, Table 3 will be used as the basis for estimating emissions of PICs from the DVP system.

Justification

These PIC generation rates are the best available testing results from testing and will not be verified.

6.2.27 Non-zero Emission Rates for Vapor Phase PIC COPCs

Assumption

The subset of PIC COPCs with vapor phase type ($F_v = 1$) are assumed to be emitted at the average unabated particulate emissions rate for PIC COPCs. The abated emissions of this subset is then determined based on the HEPA filter particulate DFs.

Justification

This subset of PIC COPCs have emissions estimated as 0 g/sec based on Assumption 6.2.15. Assumption 6.2.15 states that vapor phase COPCs have a DF of 1 in the SBS, meaning the entire amount entering the SBS passes through the SBS without being scrubbed from the off-gas stream. Since these vapor phase PIC COPCs are not captured in the SBS, they are not transferred to the DEP system in the SBS condensate stream (RLD21).

In order to assign this subset of PIC COPCs a bounding emissions estimate greater than 0 g/sec, they are assumed to be emitted at the average unabated particulate emissions rate for PIC COPCs.

6.2.28 Non-zero Emission Rates for Feed Organic COPCs without Tank Farms Average Ratios

Assumption

The subset of feed organic COPCs that do not have available data from Tank Farms sampling and therefore do not have Tank Farms Average Ratios defined in Ref. 9.2 are assumed to be emitted at the average unabated vapor emissions rate for feed organic COPCs with Tank Farms Average Ratios.

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Justification

This subset of the feed organic COPCs initially have emissions estimates of 0 g/sec, using the methodology based on Tank Farms Average Ratios. In order to assign this subset of feed organic COPCs a bounding emissions estimate greater than 0 g/sec, they are assumed to be emitted at the average unabated vapor emissions rate for feed organic COPCs with Tank Farms Average Ratios.

6.2.29 Chromium (VI) De Minimis Comparison

Assumption

For the purpose of comparing chromium (VI) emissions to the de minimis limit for chromium (VI) in WAC 173-460-150, it is assumed that all chromium emitted is chromium (VI). The emissions estimate evaluates total chromium (without specifying oxidation state) with CAS # 7440-47-3 as a feed inorganic COPC (Attachment A, Table A-3). The TAPs list in WAC 173-460-150 includes chromium (VI) with CAS # 18540-29-9 (Ref. 10.7).

Justification

The fraction of chromium present as chromium (VI) in the waste depends on the speciation of chromium compounds, however assuming that all chromium emitted is chromium (VI), for the purpose of making a comparison to the de minimis limit, is a bounding and conservative assumption.

6.2.30 Entrainment Factor Applicability for Particulate Emissions from DEP Evaporator

Assumption

The entrainment factor of 1E-3 g entrained material / g air provided in Input 2.20 is assumed to apply to the DEP evaporator for the estimation of particulate emissions.

Justification

The evaporator will be heated and under boiling conditions for water. For this reason the release fraction of 1E-3 from WAC 246-247-030 (21)(a)(ii) (Ref. 10.8) is used to estimate the entrainment of particulate from the evaporator. This value adds additional conservatism compared to the 4E-5 used for the DEP vessels. This value also does not account for any removal of particulate that will occur prior to reaching the vent system due to the presence of a bubble-cap tray, two demister pads, and three condensers in the vent path. Therefore, application of the 1E-3 entrainment factor for particulate emissions is conservative and bounding for the normal operation of the DEP evaporator.

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7 Calculations

The emissions estimate is calculated in a series of Excel spreadsheets. The Excel spreadsheet files are located in Attachment C (24590-RMCD-04955).

7.1 Radionuclide COPC Emissions

The radionuclide COPC emissions estimate calculation spreadsheet with the file name “*DFLAW Radionuclide COPC Emissions Estimate.xlsx*” is included in Attachment C. The following section describes how the spreadsheet is used to estimate organic COPC emissions.

7.1.1 COPC Maximum Batch Activities

The maximum batch activity of each radionuclide is calculated using the Excel spreadsheet titled “*DFLAW Radionuclide COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

Table 7-1 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of Batch Activities

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Radionuclide COPCs – Calc</i>	B5:B50	COPC i	--	Radionuclide COPCs identified in Attachment A
<i>Radionuclide COPCs – Calc</i>	C5:C50	r_i = Tank Farms Average ratio of COPC i , in mCi COPC / g Na	--	Tank farm average ratios from Ref. 9.2
<i>Radionuclide COPCs – Calc</i>	AF5	$n_{Na,max}$ = Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmols	Attachment G	Sodium amounts in each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Radionuclide COPCs – Calc</i>	AF6	MW_{Na} = Molecular weight of sodium, in g/mol	--	Input 2.5
<i>Radionuclide COPCs – Calc</i>	E5:E50	A_i = Maximum feed vector batch activity of COPC i , in Ci	Equation 1	Unadjusted values, see Section 7.1.1.1 for calculation of adjusted values

7.1.1.1 ICD-30 Acceptance Limits

The values for A_i calculated in Cells E5:E50 have not been adjusted to not exceed the ICD-30 acceptance limits shown in Input 2.2. The applicable values for A_i are compared to their ICD-30 limit and adjusted as needed.

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The following Excel spreadsheet images show how this comparison and adjustment is done per the methodology in Section 5.1.1.1.

Figure 7-1 – ICD-30 Acceptance Limits Calculation Spreadsheet

	A	B	C	D	E	F
1						
2	V_{max} (L)	100349.78	Attachment G			
3	$n_{Na,max}$ (kmol)	3063.63	Attachment G			
4						
5						
6	Activity Comparison/Adjustment					
7		$c_{i,limit}$ (Ci/L)		$A_{i,limit}$ (Ci)	A_i (Ci)	A_i (Ci)
8		Input 2.2		Equation 2	Equation 1	Adjusted to not exceed ICD-30 limit, if necessary
9	154Eu	1.80E-05		6.84E+00	7.53E+01	6.84E+00
10	60Co	1.10E-06		4.18E-01	5.82E+00	4.18E-01
11	99Tc	4.80E-04		1.82E+02	3.76E+01	3.76E+01
12	239Pu	3.00E-05		1.14E+01	7.02E+01	1.14E+01
13	233U	1.60E-07		6.08E-02	9.26E-01	6.08E-02
14	235U	1.70E-09		6.46E-04	1.38E-02	6.46E-04
15						
16		$c_{i,limit}$ (Ci/mol Na)		$A_{i,limit}$ (Ci)	A_i (Ci)	A_i (Ci)
17		Input 2.2		Equation 3	Equation 1	Adjusted to not exceed ICD-30 limit, if necessary
18	137Cs	3.18E-05		9.74E+01	5.57E+04	9.74E+01
19	90Sr	1.19E-03		3.65E+03	6.77E+04	3.65E+03
20	TRU	1.30E-05		3.98E+01	See next table below	3.98E+01
21						
22		A_i (Ci)	y_i	$A_{i,limit}$ (Ci)	A_i (Ci)	A_i (Ci)
23		Equation 1	Equation 4	Equation 5	Equation 1	Adjusted to not exceed ICD-30 limit, if necessary
24	237Np	1.63E-01	5.21E-04	2.08E-02	1.63E-01	2.08E-02
25	238Pu	3.74E+00	1.20E-02	4.77E-01	3.74E+00	4.77E-01
26	239Pu	7.02E+01	2.25E-01	8.95E+00	7.02E+01	8.95E+00
27	240Pu	1.54E+01	4.92E-02	1.96E+00	1.54E+01	1.96E+00
28	241Am	2.22E+02	7.12E-01	2.83E+01	2.22E+02	2.83E+01
29	242Pu	1.17E-03	3.76E-06	1.50E-04	1.17E-03	1.50E-04
30	243Am	1.03E-01	3.29E-04	1.31E-02	1.03E-01	1.31E-02
31	243Cm	1.92E-02	6.15E-05	2.45E-03	1.92E-02	2.45E-03
32	244Cm	4.24E-01	1.36E-03	5.40E-02	4.24E-01	5.40E-02
33	Total	3.12E+02				
34						
35						
36	U Fissile to U Total Comparison					
37		m_i (g)				
38		Equation 7				
39	233U				6.30E+00	
40	235U				2.99E+02	
41	238U				9.11E+05	
42						
43	$X_{U \text{ fissile to U total}}$				0.03%	

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Figure 7-2 – ICD-30 Acceptance Limits Calculation Spreadsheet with Formulas

1	A	B	C	D	E	F
2	V_{max} (L)	=100349.780368373				Attachment G
3	$\eta_{Na,max}$ (kmol)	3063.63209607692				Attachment G
4						
5						
6	Activity Comparison/Adjustment					
7		Q_{limit} (Ci/L)		A_{limit} (Ci)	A_i (Ci)	A_i (Ci)
8		Input 2.2		Equation 2	Equation 1	Adjusted to not exceed ICD-30 limit, if necessary
9	154Eu	0.000018		=B9*\$B\$2*3.785	=VLOOKUP(A9,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E9>D9,D9,E9)
10	60Co	0.0000011		=B10*\$B\$2*3.785	=VLOOKUP(A10,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E10>D10,D10,E10)
11	99Tc	0.00048		=B11*\$B\$2*3.785	=VLOOKUP(A11,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E11>D11,D11,E11)
12	239Pu	0.00003		=B12*\$B\$2*3.785	=VLOOKUP(A12,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E12>D12,D12,E12)
13	233U	0.00000016		=B13*\$B\$2*3.785	=VLOOKUP(A13,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E13>D13,D13,E13)
14	235U	0.0000000017		=B14*\$B\$2*3.785	=VLOOKUP(A14,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E14>D14,D14,E14)
15						
16		Q_{limit} (Ci/mol Na)		A_{limit} (Ci)	A_i (Ci)	A_i (Ci)
17		Input 2.2		Equation 3	Equation 1	Adjusted to not exceed ICD-30 limit, if necessary
18	137Cs	0.0000318		=B18*\$B\$3*1000	=VLOOKUP(A18,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E18>D18,D18,E18)
19	90Sr	0.00119		=B19*\$B\$3*1000	=VLOOKUP(A19,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E19>D19,D19,E19)
20	TRU	0.000013		=D20*\$D\$3*1000	See next table below	=IF(E20>D20,D20,E20)
21						
22		A_i (Ci)	Y_i	A_{limit} (Ci)	A_i (Ci)	A_i (Ci)
23		Equation 1	Equation 4	Equation 5	Equation 1	Adjusted to not exceed ICD-30 limit, if necessary
24	237Np	=VLOOKUP(A24,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B24/\$B\$33	=C24*\$D\$20	=VLOOKUP(A24,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E24>D24,D24,E24)
25	238Pu	=VLOOKUP(A25,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B25/\$B\$33	=C25*\$D\$20	=VLOOKUP(A25,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E25>D25,D25,E25)
26	239Pu	=VLOOKUP(A26,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B26/\$B\$33	=C26*\$D\$20	=VLOOKUP(A26,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E26>D26,D26,E26)
27	240Pu	=VLOOKUP(A27,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B27/\$B\$33	=C27*\$D\$20	=VLOOKUP(A27,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E27>D27,D27,E27)
28	241Am	=VLOOKUP(A28,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B28/\$B\$33	=C28*\$D\$20	=VLOOKUP(A28,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E28>D28,D28,E28)
29	242Pu	=VLOOKUP(A29,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B29/\$B\$33	=C29*\$D\$20	=VLOOKUP(A29,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E29>D29,D29,E29)
30	243Am	=VLOOKUP(A30,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B30/\$B\$33	=C30*\$D\$20	=VLOOKUP(A30,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E30>D30,D30,E30)
31	243Cm	=VLOOKUP(A31,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B31/\$B\$33	=C31*\$D\$20	=VLOOKUP(A31,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E31>D31,D31,E31)
32	244Cm	=VLOOKUP(A32,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=B32/\$B\$33	=C32*\$D\$20	=VLOOKUP(A32,'Radionuclide COPCs - Calc'!\$B\$5:\$E\$50,4,FALSE)	=IF(E32>D32,D32,E32)
33	Total	=SUM(B24:B32)				
34						
35	U Fissile to U Total Comparison					
36		m_i (g)				
37		Equation 7				
38						
39	233U	=Radionuclide COPCs - Calc'!G25				
40	235U	=Radionuclide COPCs - Calc'!G27				
41	238U	=Radionuclide COPCs - Calc'!G31				
42						
43	$X_{Ufissile to Utotal}$	=(1.25*B39+B40)/(B39+B40+B41)				

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If the ICD-30 limit is exceeded, the adjusted values are substituted for the original values in the main “Radionuclide COPCs – Calc” worksheet.

Table 7-2 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Substitution of Adjusted Values as Needed

Worksheet Title	Cell Location	Property	Calculation Method	Notes
Radionuclide COPCs – Calc	F5:F50	Adjusted values of A_i , as needed, so that ICD-30 limits are not exceeded. Values that do not require adjustment are equal to the value calculated in Column E	Figure 7-1, Figure 7-2	

Note that ^{137m}Ba and ^{90}Y are daughter products of ^{137}Cs and ^{90}Sr , respectively. Since ^{137}Cs and ^{90}Sr require adjustment to their ICD-30 limits, as shown in Figure 7-1 and Figure 7-2, ^{137m}Ba and ^{90}Y also require adjustment. The daughter products are adjusted so that their adjusted values are the same proportion to their parent as it was for the unadjusted activity. The values/formulas for ^{137m}Ba and ^{90}Y in Column F reflect this proportional adjustment.

7.1.2 COPC Maximum Batch Mass Fractions and Concentrations

The maximum batch mass fraction and concentration of each radionuclide is calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-3 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of Batch Mass Fractions and Concentrations

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Radionuclide COPCs – Calc</i>	D5:D50	SA_i , specific activity of COPC i , in Ci/g	Attachment B	Specific activities of radionuclide COPCs provided in Input 2.1
<i>Radionuclide COPCs – Calc</i>	G5:G50	m_i = Maximum feed vector batch mass of COPC i , in g	Equation 8	
<i>Radionuclide COPCs – Calc</i>	AF7	$V_{batch,avg}$ = Average total feed vector batch volume, in gal	Attachment G	Volumes of each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Radionuclide COPCs – Calc</i>	AF8	$\rho_{batch,avg}$ = Average total vector batch density, in g/cc	Attachment G	Densities of each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Radionuclide COPCs – Calc</i>	AF9	$m_{batch,avg}$ = Average total feed vector batch mass, in g	Equation 9	
<i>Radionuclide COPCs – Calc</i>	H5:H50	x_i = Maximum feed vector batch mass fraction of COPC i	Equation 10	
<i>Radionuclide COPCs – Calc</i>	I5:I50	c_i = Maximum feed vector batch concentration of COPC i , in g/L	Equation 11	

7.1.3 Radionuclide COPC Emissions Due to Entrainment of Particles/Aerosols

The unabated and abated emissions of radionuclide COPCs emitted due to entrainment are calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-4 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of Radionuclide COPC Emissions Due to Entrainment

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Radionuclide COPCs – Calc</i>	AF10	$\bar{m}_{ves,vent}$ = Total mass flowrate of the DVP system except for evaporator, in lb/hr	Assumption 6.1.4	
<i>Radionuclide COPCs – Calc</i>	AF11	EF_{ves} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.3	Assumption 6.2.3
<i>Radionuclide COPCs – Calc</i>	AF12	$\bar{m}_{evap,vent}$ = Mass flowrate of the evaporator vent stream, in lb/hr	Assumption 6.1.4	
<i>Radionuclide COPCs – Calc</i>	AF13	EF_{evap} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.20	Assumption 6.2.30
<i>Radionuclide COPCs – Calc</i>	AF14	$\bar{m}_{tot,entrained}$ = Total mass flowrate of entrained material, in g/min	Equation 12	
<i>Radionuclide COPCs – Calc</i>	K5:K50 (except K13 and K41)	$\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC <i>i</i> , in g/min	Equation 13	Emissions of vapor phase radionuclide COPCs (¹⁴ C and ³ H) are calculated in Section 7.1.4
<i>Radionuclide COPCs – Calc</i>	L5:L50 (except L13 and L41)	$\bar{A}_{i,unabated}$ = Unabated activity of COPC <i>i</i> emitted per year, in Ci/year	Equation 14	Emissions of vapor phase radionuclide COPCs (¹⁴ C and ³ H) are calculated in Section 7.1.4
<i>Radionuclide COPCs – Calc</i>	AF15	$DF_{HEPA,primary}$ = Decontamination factor of primary HEPA filter	Assumption 6.2.10	
<i>Radionuclide COPCs – Calc</i>	AF16	$DF_{HEPA,secondary}$ = Decontamination factor of secondary HEPA filter	Assumption 6.2.10	
<i>Radionuclide COPCs – Calc</i>	N5:N50 (except N13 and N41)	$\bar{A}_{i,abated}$ = Abated activity of COPC <i>i</i> emitted per year, in Ci/year	Equation 15	Emissions of vapor phase radionuclide COPCs (¹⁴ C and ³ H) are calculated in Section 7.1.4

7.1.4 Vapor Phase Radionuclide COPCs

7.1.4.1 Sources of Vapor Phase Radionuclide COPCs

The volume of residual feed material in the flush to DEP-VSL-00001 and the total mass of ¹⁴C and ³H flushed annually to DEP-VSL-00001 are calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-5 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of Sources of Vapor Phase Radionuclide COPCs

Worksheet Title	Cell Location	Property	Calculation Method	Notes
Radionuclide COPCs – Calc	AF17	V_{flush} = Total volume of LAW feed line flush, in gal	Input 2.4, Assumption 6.1.3	
Radionuclide COPCs – Calc	AF18	<i>Dilution Factor</i> = Flush dilution factor	Assumption 6.1.2	
Radionuclide COPCs – Calc	AF19	$V_{residual\ feed}$ = Volume of residual feed in a LAW feed line flush, in L	Equation 16	
Radionuclide COPCs – Calc	AF20	F_{flush} = Frequency of LAW feed line flush, in 1/hr	Assumption 6.1.3	
Radionuclide COPCs – Calc	Q13 and Q41	$\bar{m}_{i,flush}$ = Mass of COPC <i>i</i> flushed to DEP-VSL-0001 annually, in g/yr	Equation 17	

7.1.4.2 Vapor Phase Radionuclide COPC Emissions

7.1.4.2.1 ¹⁴C Emissions

The unabated and abated emissions of ¹⁴C are calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

Table 7-6 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of ¹⁴C Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
Radionuclide COPCs – Calc	R13	$\bar{A}_{i,unabated}$ = Unabated activity of COPC <i>i</i> emitted per year, in Ci/year	Equation 18	
Radionuclide COPCs – Calc	S13	$\bar{A}_{i,abated}$ = Abated activity of COPC <i>i</i> emitted per year, in Ci/year	Equal to Cell R13	Vapor phase DF through HEPA filter is 1 (Assumption 6.2.10)

7.1.4.2.2 ³H Emissions

The unabated and abated emissions of ³H are calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-7 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of ³H Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
Radionuclide COPCs – Calc	AF21	$MDR_{3H, evaporator}$ = Evaporator MDR for ³ H	Assumption 6.1.35	
Radionuclide COPCs – Calc	AF22	$MDR_{3H, primary condenser}$ = Primary condenser MDR for ³ H	Assumption 6.1.35	
Radionuclide COPCs – Calc	AF23	$MDR_{3H, inter-condenser}$ = Inter condenser MDR for ³ H	Assumption 6.1.35	
Radionuclide COPCs – Calc	AF24	$MDR_{3H, combined}$ = Combined MDR for ³ H	Equation 20	
Radionuclide COPCs – Calc	R41	$\bar{A}_{i, unabated}$ = Unabated activity of COPC <i>i</i> emitted per year, in Ci/year	Equation 21	
Radionuclide COPCs – Calc	S41	$\bar{A}_{i, abated}$ = Abated activity of COPC <i>i</i> emitted per year, in Ci/year	Equal to Cell R41	Vapor phase DF through HEPA filter is 1 (Assumption 6.2.10)

7.1.5 ACV Exhaust System Radionuclide COPC Emissions

The unabated and abated emissions of radionuclide COPCs from the ACV exhaust system are calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-8 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of ACV Exhaust System Radionuclide COPC Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
Radionuclide COPCs – Calc	V5:V50	$\bar{A}_{i,unabated,ACV}$ = Unabated activity of COPC i emitted per year from the ACV Exhaust system, in Ci/year	Equation 22	
Radionuclide COPCs – Calc	W5:W50	$\bar{A}_{i,abated,ACV}$ = Abated activity of COPC i emitted per year from the ACV Exhaust system (Single-stage HEPA), in Ci/year	Apply DF of 2000 for entrained emissions and DF of 1 for vapor emissions (Assumption 6.2.10)	
Radionuclide COPCs – Calc	X5:X50	$\bar{A}_{i,abated,ACV}$ = Abated activity of COPC i emitted per year from the ACV Exhaust system (Dual-stage HEPA), in Ci/year	Apply DF of 200,000 for entrained emissions and DF of 1 for vapor emissions (Assumption 6.2.10)	

7.1.6 Annual Possession Quantities

The APQs for radionuclide COPCs in the DEP system are calculated using the Excel spreadsheet titled “DFLAW Radionuclide COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

Table 7-9 “DFLAW Radionuclide COPC Emissions Estimate.xlsx” Calculation of APQs

Worksheet Title	Cell Location	Property	Calculation Method	Notes
Radionuclide COPCs – Calc	AF25	$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm	Assumption 6.1.7	
Radionuclide COPCs – Calc	AF26	$V_{evap,throughput}$ = Annual volume processed through DEP evaporator, L	Equation 24	100% uptime based on Assumption 6.2.13
Radionuclide COPCs – Calc	Z5:Z50 (except Z13, Z41)	APQ_i = Annual Possession Quantity of COPC i , in Ci/yr	Equation 23	
Radionuclide COPCs – Calc	Z13, Z41	APQ_i = Annual Possession Quantity of COPC i , in Ci/yr	Equation 25	

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7.2 Organic COPC Emissions

The organic COPC emissions estimate calculation spreadsheet with the file name “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” is included in Attachment C. The following section describes how the spreadsheet is used to estimate organic COPC emissions.

7.2.1 Feed Organic COPC Emissions

7.2.1.1 Adjustment of Tank Farms Average Ratios

The Tank Farms Average ratios are adjusted per the methodology in Section 5.2.1.1 using the Excel spreadsheet titled “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

Table 7-10 “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Adjustment of Tank Farms Average Ratios

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Organic COPCs – Calc</i>	C5:C141	r_i = Tank farm ratio for COPC i , g COPC / g TOC		Ref. 9.2
<i>Feed Organic COPCs – Calc</i> <i>Non-COPCs Organics</i>	D5:D141 D5:D58	\bar{c}_i = Tank Farms Average ratio for COPC i , in g COPC-as-Carbon / g TOC (include non-COPC ratios)		Ref. 9.2
<i>Feed Organic COPCs – Calc</i>	D143	$\sum \bar{c}_i$ = Sum of all Tank Farms Average ratios (COPC and non-COPC) = 0.691		
<i>Feed Organic COPCs – Calc</i> <i>Non-COPCs Organics</i>	E5:E141 E5:E58	$\bar{c}_{i,scaled}$ = Scaled Tank Farms Average ratio for COPC i to account for unspiciated organic carbon, g COPC-as-Carbon / g TOC	Equation 26	Assumption 6.2.12
<i>Feed Organic COPCs – Calc</i>	F5:F141	$\bar{r}_{i,scaled}$ = Scaled tank farm ratio for COPC i to account for unspiciated organic carbon, g COPC / g TOC	Equation 27	

7.2.1.2 Determination of Feed Vector TOC Values

The adjusted batch TOC values in the DFLAW Bounding Feed Vector are calculated using the Excel spreadsheet titled “*Bounding_DFLAW-batches-to-wtp_TOTALS.xlsx*” shown in Attachment C. The DFLAW Bounding Feed Vector batch information is also shown in Attachment G. The following table describes how these values are calculated within the spreadsheet:

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Table 7-11 “*Bounding_DFLAW-batches-to-wtp_TOTALS.xlsx*” Calculation of Adjusted TOC Values

Worksheet Title	Cell Location	Property	Calculation Method	Notes
TOTALS	G4:G180	TOC_{batch} = moles of TOC delivered to WTP in a feed vector batch, in kmol		Provided in Ref. 9.2
TOTALS	H4:H180	Ox_{batch} = moles of oxalate delivered to WTP in a feed vector batch, in kmol		Provided in Ref. 9.2
TOTALS	N3	MW_c = Molecular weight of carbon, g/mol	Input 2.6	
TOTALS	N4	γ = moles of carbon per mole of oxalate		2 moles of Carbon for every 1 mole of oxalate ($C_2O_4^{2-}$)
TOTALS	I4:I180	TOC_{adj} = adjusted mass of TOC delivered to WTP in a feed vector batch, in kg	Equation 28	The maximum value for TOC_{adj} is shown in Cell I181

7.2.1.3 COPC Maximum Batch Masses, Mass Fractions, and Concentrations

Maximum batch masses, mass fractions, and concentrations are calculated using the Excel spreadsheet titled “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-12 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Calculation of Maximum Batch Masses, Mass Fractions, and Concentrations

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Organic COPCs – Calc</i>	AA5	$TOC_{adj,max}$ = Maximum batch adjusted mass of TOC delivered to WTP in a feed vector batch, in g	Equation 28	Value copied from “ <i>Bounding_DFLAW-batches-to-wtp_TOTALS.xlsx</i> ” Worksheet “ <i>TOTALS</i> ” Cell I183
<i>Feed Organic COPCs – Calc</i>	G5:G141	m_i = Maximum feed vector batch mass of COPC i , in g	Equation 29	
<i>Feed Organic COPCs – Calc</i>	AA6	$V_{batch,avg}$ = Average total feed vector batch volume, in gal	Attachment G	Volumes of each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Feed Organic COPCs – Calc</i>	AA7	$\rho_{batch,avg}$ = Average total vector batch density, in g/cc	Attachment G	
<i>Feed Organic COPCs – Calc</i>	AA8	$m_{batch,avg}$ = Average total feed vector batch mass, in g	Equation 9	
<i>Feed Organic COPCs – Calc</i>	H5:H141	x_i = Maximum feed vector batch mass fraction of COPC i	Equation 10	
<i>Feed Organic COPCs – Calc</i>	I5:I141	c_i = Maximum feed vector batch concentration of COPC i , in g/L	Equation 11	

7.2.1.4 Other Physical Properties

Physical properties for organic COPCs have been compiled in Ref. 9.15, Attachment A. Certain physical properties of the feed organic COPCs were extracted from Ref. 9.15, Attachment A for use in the Excel spreadsheet titled “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” shown in Attachment C. The worksheet titled “*COPC Data*” within “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” contains the physical property tables from Ref. 9.15, Attachment A in spreadsheet form. The Vlookup function in Excel is used to search the “*COPC Data*” worksheet by each COPC’s Chemical Abstracts Service (CAS) number and import the desired physical property into the “*Feed Organic COPCs – Calc*” worksheet. The following table describes where these values are located within the spreadsheet:

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Table 7-13 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Other Physical Properties

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Organic COPCs – Calc</i>	J5:J141	$F_{v,i}$ = Vapor phase partitioning coefficient of COPC i	Vlookup of Column AD in “COPC Data” worksheet	
<i>Feed Organic COPCs – Calc</i>	K5:K141	Phase type based on F_v value	$F_v = 1.0$; phase type = vapor $0.05 \leq F_v < 1.0$; phase type = particle-bound $F_v < 0.05$; phase type = particle	
<i>Feed Organic COPCs – Calc</i>	L5:L141	$k'_{H,i}$ = Henry’s Law constant for COPC i , in atm*m ³ /mol	Vlookup of Column X in “COPC Data” worksheet	
<i>Feed Organic COPCs – Calc</i>	M5:M141	MW_i = Molecular weight of COPC	Vlookup of Column M in “COPC Data” worksheet	
<i>Feed Organic COPCs – Calc</i>	N5:N141	Feed or Feed/PIC COPC	Vlookup of Column F in “COPC Data” worksheet	

7.2.1.5 Vapor Phase Feed Organic COPC Emissions

The vapor phase feed organic COPC emissions are calculated using the Excel spreadsheet titled “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” shown in Attachment C . The following table describes how these values are calculated within the spreadsheet:

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Table 7-14 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Vapor Phase Feed Organic COPC Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Organic COPCs – Calc</i>	AA9	V_{flush} = Total volume of LAW feed line flush, in gal	Input 2.4, Assumption 6.1.3	
<i>Feed Organic COPCs – Calc</i>	AA10	<i>Dilution Factor</i> = Flush dilution factor	Assumption 6.1.2	
<i>Feed Organic COPCs – Calc</i>	AA11	$V_{residual\ feed}$ = Volume of residual feed in a LAW feed line flush, in L	Equation 16	
<i>Feed Organic COPCs – Calc</i>	AA12	F_{flush} = Frequency of LAW feed line flush, in hr	Assumption 6.1.3	
<i>Feed Organic COPCs – Calc</i>	P5:P141	$\bar{m}_{i,flush}$ = Mass of COPC <i>i</i> flushed to DEP-VSL-0001 annually, in g/yr	Equation 17	
<i>Feed Organic COPCs – Calc</i>	Q5:Q141	$\bar{m}_{i,vap,unabated}$ = Unabated vapor phase emissions of COPC <i>i</i> , in g/sec	Equation 30	
<i>Feed Organic COPCs – Calc</i>	R5:R141	$\bar{m}_{i,vap,abated}$ = Abated vapor phase emissions of COPC <i>i</i> , in g/sec	Same as $\bar{m}_{i,vap,unabated}$	Assumption 6.2.10

7.2.1.6 Particle Phase Feed Organic COPC Emissions

The particle phase feed organic COPC emissions are calculated using the Excel spreadsheet titled “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” shown in Attachment C . The following table describes how these values are calculated within the spreadsheet:

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Table 7-15 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Particle Phase Feed Organic COPC Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Organic COPCs – Calc</i>	AA13	$\bar{m}_{ves,vent}$ = Total mass flowrate of the DVP system except for evaporator, in lb/hr	Assumption 6.1.4	
<i>Feed Organic COPCs – Calc</i>	AA14	EF_{ves} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.3	Assumption 6.2.3
<i>Feed Organic COPCs – Calc</i>	AA15	$\bar{m}_{evap,vent}$ = Mass flowrate of the evaporator vent stream, in lb/hr	Assumption 6.1.4	
<i>Feed Organic COPCs – Calc</i>	AA16	EF_{evap} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.20	Assumption 6.2.30
<i>Feed Organic COPCs – Calc</i>	AA17	$\bar{m}_{tot,entrained}$ = Total mass flowrate of entrained material, in g/min	Equation 12	
<i>Feed Organic COPCs – Calc</i>	T5:T141	$\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC <i>i</i> , in g/min	Equation 31	
<i>Feed Organic COPCs – Calc</i>	U5:U141	$\bar{m}_{i,part,unabated}$ = Unabated particulate emissions of COPC <i>i</i> , in g/sec	Equation 32	
<i>Feed Organic COPCs – Calc</i>	AA18	$DF_{HEPA,primary}$ = Decontamination factor of primary HEPA filter	Assumption 6.2.10	
<i>Feed Organic COPCs – Calc</i>	AA19	$DF_{HEPA,secondary}$ = Decontamination factor of secondary HEPA filter	Assumption 6.2.10	
<i>Feed Organic COPCs – Calc</i>	V5:V141	$\bar{m}_{i,part,abated}$ = Abated particulate emissions of COPC <i>i</i> , in g/sec	Equation 33	

7.2.2 PIC COPC Emissions

7.2.2.1 PIC Generation Rates

The PIC generation rates are calculated using the Excel spreadsheet titled “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” shown in Attachment C . The following table describes how these values are calculated within the spreadsheet:

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Table 7-16 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” PIC Generation Rates

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>PIC COPCs – Calc</i>	D5:D213	$F_{v,i}$ = Vapor phase partitioning coefficient of COPC i	Vlookup of Column AD in “COPC Data” worksheet	
<i>PIC COPCs – Calc</i>	E5:E213	Phase type based on F_v value	$F_v = 1.0$; phase type = vapor $0.05 \leq F_v < 1.0$; phase type = particle-bound $F_v < 0.05$; phase type = particle	
<i>PIC COPCs – Calc</i>	F5:F213	$GR_{PIC,i}$ = Generation rate of PIC COPC i , in mg (or g) PIC generated / mg (or g) melter feed TOC	Vlookup of Column C in “VSL PIC Data” worksheet	Assumptions 6.2.17, 6.2.26
<i>PIC COPCs – Calc</i>	Q5	$TOC_{MF,max}$ = Maximum mass flowrate of TOC in melter feed stream LFP04 from PIBOD model runs, in kg/hr	Maximum LFP04 TOC value rounded up to 20 kg/hr See Attachment F values extracted from PIBOD runs	Assumption 6.1.15
<i>PIC COPCs – Calc</i>	G5:G213	$\bar{m}_{melter,i}$ = Mass flowrate of PIC COPC i generated in the melter, in g/sec	Equation 34	

7.2.2.2 PIC COPC Emissions

The PIC COPC emissions are calculated using the Excel spreadsheet titled “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-17 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” PIC COPC Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>PIC COPCs – Calc</i>	H5:H213	$\bar{m}_{SBS,i}$ = Mass flowrate of PIC COPC <i>i</i> captured in the SBS, in g/sec	Equation 35	
<i>PIC COPCs – Calc</i>	Q6	V_{RLD21} = Transfer volume of stream RLD21, in gallons	Assumption 6.2.20	
<i>PIC COPCs – Calc</i>	Q7	ρ_{RLD21} = Density of stream RLD21 from PIBOD, in g/L	Input 2.14	
<i>PIC COPCs – Calc</i>	Q8	F_{RLD21} = Frequency of transfer from RLD-VSL-00005 to DEP-VSL-00002, in 1/hr	Assumption 6.2.19	
<i>PIC COPCs – Calc</i>	Q9	\bar{m}_{RLD21} = Mass flowrate of stream RLD21, in g/sec	Equation 36	
<i>PIC COPCs – Calc</i>	I5:I213	$x_{RLD21,i}$ = Mass fraction of PIC COPC <i>i</i> in Stream RLD21	Equation 37	
<i>PIC COPCs – Calc</i>	Q10	$\bar{m}_{ves,vent}$ = Total mass flowrate of the DVP system except for evaporator, in lb/hr	Assumption 6.1.4	
<i>PIC COPCs – Calc</i>	Q11	EF_{ves} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.3	Assumption 6.2.3
<i>PIC COPCs – Calc</i>	Q12	$\bar{m}_{evap,vent}$ = Mass flowrate of the evaporator vent stream, in lb/hr	Assumption 6.1.4	
<i>PIC COPCs – Calc</i>	Q13	EF_{evap} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.20	Assumption 6.2.30
<i>PIC COPCs – Calc</i>	Q14	$\bar{m}_{tot,entrained}$ = Total mass flowrate of entrained material, in g/min	Equation 12	
<i>PIC COPCs – Calc</i>	J5:J213	$\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC <i>i</i> , in g/min	Equation 13	
<i>PIC COPCs – Calc</i>	K5:K213	$\bar{m}_{i,part,unabated}$ = Unabated particulate emissions of COPC <i>i</i> , in g/sec	Equation 32	
<i>PIC COPCs – Calc</i>	Q15	$DF_{HEPA,primary}$ = Decontamination factor of primary HEPA filter	--	Assumption 6.2.10
<i>PIC COPCs – Calc</i>	Q16	$DF_{HEPA,secondary}$ = Decontamination factor of secondary HEPA filter	--	Assumption 6.2.10
<i>PIC COPCs – Calc</i>	L5:L213	$\bar{m}_{i,part,abated}$ = Abated particulate emissions of COPC <i>i</i> , in g/sec	Equation 33	

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7.2.3 Feed/PIC Organic COPC Emissions

Particulate emissions for the subset of organic COPCs identified as being present as both Feed Organics and PICs will be the sum of the particulate emissions calculated in Sections 7.2.1.6 and 7.2.2.2. This is reflected in the following section describing how the results are summarized.

7.2.4 Organic COPC Summary and Comparison to De Minimis Emissions Limits

The results from Sections 7.2.1, 7.2.2, and 7.2.3 are presented in summary tables. The summary table for feed organic COPCs is contained in “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Worksheet “*Organic Summary Table*” shown in Attachment C. The PIC COPC summary table is contained in Worksheet “*PIC Summary Table*”. The following table describes how these values are calculated within the spreadsheet:

Table 7-18 “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Summary Tables

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Organic Summary Table</i>	D7:D143	Feed or Feed/PIC COPC	Vlookup of Column N in “ <i>Feed Organic COPCs - Calc</i> ” worksheet	
<i>Organic Summary Table</i>	E7:E143	$\bar{m}_{i,vap,unabated}$, in g/sec	Vlookup of Column Q in “ <i>Feed Organic COPCs - Calc</i> ” worksheet	Results before any Henry’s Law Adjustment
<i>Organic Summary Table</i>	F7:F143	$\bar{m}_{i,vap,unabated}$, in g/sec	Vlookup of Column Q in “ <i>Organic COPCs - Calc</i> ” worksheet or value from “ <i>Henry’s Law</i> ” worksheet (see Section 7.2.4.1.3)	Results after any Henry’s Law Adjustment Values initially shown as 0 g/s in this column (representing feed organic COPCs without Tank Farms Average Ratios) will be adjusted to bounding emissions estimates as described in Section 7.2.4.2.2.

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Worksheet Title	Cell Location	Property	Calculation Method	Notes
Organic Summary Table	H7:H143	$\bar{m}_{i,part,unabated}$, in g/sec	Vlookup of Column U in “ <i>Feed Organic COPCs - Calc</i> ” worksheet OR IF the COPC is a Feed/PIC THEN the sum of Vlookup of Column U in “ <i>Feed Organic COPCs - Calc</i> ” worksheet AND Vlookup of Column K in “ <i>PIC COPCs - Calc</i> ” worksheet	Values initially shown as 0 g/s for Feed/PIC COPCs in this column will be adjusted to bounding emissions estimates as described in Section 7.2.4.2.1.
Organic Summary Table	J7:J143	$\bar{m}_{i,total,unabated}$, in g/sec	Sum of unabated vapor and particle emissions	
Organic Summary Table	K7:K143	$\bar{m}_{i,vap,abated}$, in g/sec	Vlookup of Column R in “ <i>Feed Organic COPCs - Calc</i> ” worksheet	Results before any Henry’s Law Adjustment
Organic Summary Table	L7:L143	$\bar{m}_{i,vap,abated}$, in g/sec	Vlookup of Column R in “ <i>Feed Organic COPCs - Calc</i> ” worksheet or value from “ <i>Henry’s Law</i> ” worksheet (see Section 7.2.4.1.3)	Results after any Henry’s Law Adjustment
Organic Summary Table	M7:M143	$\bar{m}_{i,part,abated}$, in g/sec	Equation 30	
Organic Summary Table	N7:N143	$\bar{m}_{i,total,abated}$, in g/sec	Sum of abated vapor and particle emissions	
PIC Summary Table	D7:D216	PIC or Feed/PIC COPC	Vlookup of Column C in “ <i>PIC COPCs - Calc</i> ” worksheet	

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Worksheet Title	Cell Location	Property	Calculation Method	Notes
PIC Summary Table	E7:E177	$\bar{m}_{i,part,unabated}$, in g/sec	Vlookup of Column K in “PIC COPCs - Calc” worksheet	Feed/PIC COPCs have been sorted to the bottom of the table and their results are reported with the feed organic COPCs as described in Section 7.2.3 Values initially shown as 0 g/s for PIC COPCs in this column will be adjusted to bounding emissions estimates as described in Section 7.2.4.2.1
PIC Summary Table	G7:G177	$\bar{m}_{i,part,abated}$, in g/sec	Vlookup of Column L in “PIC COPCs - Calc” worksheet	Feed/PIC COPCs have been sorted to the bottom of the table and their results are reported with the feed organic COPCs as described in Section 7.2.3

Note that Row 144 of the “*Organic Summary Table*” worksheet contains the results for carbon disulfide, copied from the Excel spreadsheet “*DFLAW Inorganic COPC Emissions Estimate.xlsx*”.

Next, the total abated emissions values are compared to de minimis emissions limits for TAPs established in WAC 173-460-150 (Input 2.13), using the worksheet “*WAC 173-460-150*”.

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Table 7-19 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” De Minimis Value Comparison

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>WAC 173-460-150</i>	G5:G400	$\bar{m}_{i,dm}$ = de minimis emissions limit for COPC <i>i</i> , lb/averaging period	Input 2.13	
<i>WAC 173-460-150</i>	I5:I400	$\bar{m}_{i,dm,standard}$ = de minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Equation 38	
<i>WAC 173-460-150</i>	J5:J400	$\bar{m}_{i,total,unabated}$ Feed organic COPCs – Total Abated Emissions of COPC <i>i</i> , in lb/yr	Vlookup of Column H in “Organic Summary Table” worksheet	Converted from g/sec to lb/yr
<i>WAC 173-460-150</i>	K5:K400	$\bar{m}_{i,total,unabated}$ PIC COPCs – Total Abated Emissions of COPC <i>i</i> , in lb/yr	Vlookup of Column E in “Organic Summary Table” worksheet	Converted from g/sec to lb/yr
<i>WAC 173-460-150</i>	M5:M400	Difference: Feed Organic COPC minus de minimis, in lb/yr	Column J minus Column I	If value is positive, vapor emissions of COPC will be reevaluated using Henry's Law Analysis
<i>WAC 173-460-150</i>	N5:N400	Difference: PIC COPC minus de minimis, in lb/yr	Column K minus Column I	No positive values in Column N, meaning all PIC COPC unabated emissions are below the de minimis value

The comparison in worksheet “*WAC 173-460-150*” did not find any PIC COPCs that exceeded their de minimis values.

The comparison did find seven feed organic COPCs with unabated emissions that exceed their de minimis values. These COPCs, shown in the following table, will be reevaluated using a Henry’s Law method for estimating the vapor phase emissions in place of Assumption 6.2.16 that the entire vapor phase is emitted during processing.

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Table 7-20 Feed Organic COPCs that Exceed De Minimis Value

CAS #	COPC	De minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Feed Organic COPCs - Total Unabated Emissions of COPC <i>i</i> , in lb/yr	Difference: Feed Organic COPC minus de minimis, in lb/yr
88-06-2	2,4,6-Trichlorophenol	4.80E-01	3.46E+00	2.98E+00
121-14-2	2,4-Dinitrotoluene	1.07E-01	3.94E+00	3.83E+00
91-20-3	Naphthalene	2.82E-01	3.68E+00	3.40E+00
62-75-9	n-Nitrosodimethylamine	2.08E-03	1.85E-02	1.64E-02
621-64-7	n-Nitrosodi-n-propylamine	4.80E-03	3.49E+00	3.49E+00
59-89-2	n-Nitrosomorpholine	5.05E-03	7.96E+00	7.95E+00
1336-36-3	Polychlorinated Biphenyls, NOS	1.68E-02	1.80E+00	1.79E+00

7.2.4.1 Henry's Law Analysis

The subset of feed organic COPCs in Table 7-20 that exceed their de minimis emissions limit are evaluated a second time using a Henry's Law analysis. This analysis is shown in the Excel spreadsheet titled "*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*" Worksheet "*Henry's Law*" shown in Attachment C.

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Table 7-21 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Henry’s Law Analysis Setup

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Henry’s Law</i>	U5	$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm	Assumption 6.1.7	
<i>Henry’s Law</i>	U6	$V_{evap,throughput}$ = Annual volume processed through DEP evaporator, L	Equation 24	100% uptime based on Assumption 6.2.13
<i>Henry’s Law</i>	C5:C11	$\bar{m}_{i,flush}$ = Mass of COPC <i>i</i> flushed to DEP-VSL-0001 annually, in g/yr	Vlookup of Column P in “Feed Organic COPCs - Calc” worksheet	
<i>Henry’s Law</i>	D5:D11	$c_{i,flush}$ = Concentration of COPC <i>i</i> based on amount received in feed line flush, g/L	Equation 39	
<i>Henry’s Law</i>	E5:E11	$k'_{H,i}$ = Henry’s Law constant for COPC <i>i</i> , in atm*m ³ /mol	Vlookup of Column L in “Feed Organic COPCs - Calc” worksheet	
<i>Henry’s Law</i>	F5:F11	MW_i = Molecular weight of COPC <i>i</i> , in g/mol	Vlookup of Column M in “Feed Organic COPCs - Calc” worksheet	

7.2.4.1.1 Case 1: Vessel Vent Streams

The vapor emissions from the all vessel vent streams, except for the vent from the evaporator system, are estimated using a combined Henry’s Law analysis.

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Table 7-22 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Case 1: Vessel Vent Streams

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Henry's Law</i>	U7	P_{vessel} = DEP system vessel pressure, in atm	Assumption 6.1.10	
<i>Henry's Law</i>	H5:H11	y_i = Mole fraction COPC i in the vapor phase	Equation 44	
<i>Henry's Law</i>	U8	$\bar{m}_{tot,vent}$ = Total mass flowrate of the DVP system, in lb/hr	Assumption 6.1.4	
<i>Henry's Law</i>	U9	MW_{air} = Average molecular weight of air, g/mol	Input 2.8	
<i>Henry's Law</i>	I5:I11	$\bar{m}_{vapor,vent,i}$ = Vapor phase mass flow rate of COPC i in vessel vent stream, in g/sec	Equation 45	

7.2.4.1.2 Case 2: Evaporator Vent Stream

The vapor emissions from the evaporator system vent are estimated separately from the vessel vent streams due to differing operating pressure and the inclusion of condensers in the evaporator overheads. The evaporator system vents from the after-condenser. The vapor emissions from the evaporator separator vessel are estimated using a Henry's Law analysis.

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Table 7-23 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Case 2: Evaporator Vent Stream

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Henry's Law</i>	U10	P_{evap} = DEP Evaporator nominal operating pressure, in atm	Assumption 6.1.9	
<i>Henry's Law</i>	K5:K11	y_i = Mole fraction COPC i in the vapor phase	Equation 44	
<i>Henry's Law</i>	U14	$\bar{V}_{tot,evap}$ = Total volumetric flowrate of the evaporator overheads stream, in gpm	Assumption 6.1.8	
<i>Henry's Law</i>	U12	MW_{water} = Molecular weight of water, in g/mol	Input 2.7	
<i>Henry's Law</i>	U13	ρ_{water} = Density of water, in g/L	Equation 47	
<i>Henry's Law</i>	U11	T_{evap} = Normal operating temperature of the DEP evaporator, °C	Assumption 6.1.9	
<i>Henry's Law</i>	L5:L11	$\bar{m}_{vapor,evap,i}$ = Vapor phase mass flow rate of COPC i in evaporator overheads stream, in g/sec	Equation 46	
<i>Henry's Law</i>	U15	$MDR_{VOC,primary\ condenser}$ = VOCs MDR for primary condenser	Assumption 6.1.14	
<i>Henry's Law</i>	U16	$MDR_{VOC,inter-condenser}$ = VOCs MDR for inter-condenser	Assumption 6.1.14	
<i>Henry's Law</i>	U17	$MDR_{VOC,combined}$ = VOCs MDR for primary condenser	Equation 48	
<i>Henry's Law</i>	M5:M11	$\bar{m}_{vapor,evap,tot,i}$ = Vapor phase mass flowrate of COPC i in the evaporator vent stream, g/sec	Equation 49	

7.2.4.1.3 Henry's Law Analysis Emissions and Mass Check

The unabated emissions based on the Henry's Law analyses from Case 1 and Case 2 are combined to give the total unabated emissions. In some cases, $\bar{m}_{unabated,Henry,i}$ may exceed $\bar{m}_{i,vap,unabated}$ (from Equation 30 in Section 7.2.1.5). Since $\bar{m}_{i,vap,unabated}$ is based on the emission of the entire mass of the vapor phase of a COPC that is flushed to the DEP system, values of $\bar{m}_{unabated,Henry,i}$ that exceed $\bar{m}_{i,vap,unabated}$ will be capped at the value for $\bar{m}_{i,vap,unabated}$.

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Table 7-24 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Case 1: Vessel Vent Streams

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Henry’s Law</i>	O5:O11	$\bar{m}_{unabated, Henry, i}$ = Unabated vapor emissions of COPC <i>i</i> , in g/sec	Equation 50	If $\bar{m}_{unabated, Henry, i}$ is greater than $\bar{m}_{i, vap, unabated}$ (from Worksheet “ <i>Feed Organic COPCs – Calc</i> ” Column Q) then limit value to $\bar{m}_{i, vap, unabated}$.
<i>Henry’s Law</i>	P5:P11	$\bar{m}_{abated, Henry, i}$ = Abated vapor phase emissions of COPC <i>i</i> , in g/sec	Same as $\bar{m}_{unabated, Henry, i}$	Assumption 6.2.10

The values for $\bar{m}_{unabated, Henry, i}$ and $\bar{m}_{abated, Henry, i}$ for the COPCs evaluated in the “*Henry’s Law*” worksheet are manually entered in the corresponding cells in Columns F and J of Worksheet “*Organic Summary Table*”. Then the total unabated emissions of these COPCs are compared again to the WAC 173-460-150 de minimis values. The following table shows the results:

Table 7-25 Post Henry’s Law Comparison to De Minimis Values

CAS #	COPC	De minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Feed Organic COPCs - Total Unabated Emissions of COPC <i>i</i> , in lb/yr	Difference: Feed Organic COPC minus de minimis, in lb/yr
88-06-2	2,4,6-Trichlorophenol	4.80E-01	1.17E-01	-3.63E-01
121-14-2	2,4-Dinitrotoluene	1.07E-01	1.58E-03	-1.05E-01
91-20-3	Naphthalene	2.82E-01	3.68E+00	3.40E+00
62-75-9	n-Nitrosodimethylamine	2.08E-03	1.46E-04	-1.93E-03
621-64-7	n-Nitrosodi-n-propylamine	4.80E-03	3.40E-02	2.92E-02
59-89-2	n-Nitrosomorpholine	5.05E-03	8.43E-04	-4.21E-03
1336-36-3	Polychlorinated Biphenyls, NOS	1.68E-02	1.80E+00	1.79E+00

The comparison shows that Naphthalene (91-20-3), n-Nitrosodi-n-propylamine (621-64-7), and Total PCBs (1336-36-3) are the only organic COPCs that exceed their de minimis values.

7.2.4.2 Adjustment of COPCs with Zero Emissions

7.2.4.2.1 Adjustment of PIC COPCs with Zero Emissions

To calculate the average non-zero unabated particulate emissions rate for PIC COPCs, first Column E in “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Worksheet “*PIC COPCs – Calc*” is filtered to hide the PIC COPCs with a vapor phase type. The average unabated particulate emissions (Column K) of the remaining particle/particle-bound PIC COPCs is calculated in Cell K215. The resulting average value is then assigned in Column K to each of the vapor phase type PIC COPCs and subsequently treated

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as a particulate emission for calculation of abated emissions in Column L (Assumption 6.2.27). These adjusted results are then reported on the PIC COPC summary table (Table 8-5) for PIC COPCs and the feed organic COPC summary table (Table 8-4) for Feed/PIC COPCs.

7.2.4.2.2 Adjustment of Feed Organic COPCs with Zero Emissions

To calculate the average non-zero unabated vapor emissions rate for feed COPCs, first Column F in “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Worksheet “*Organic Summary Table*” is filtered to hide the feed COPCs without Tank Farm Average Ratios, indicated by a vapor emissions rate of 0 g/s in Column F. The average unabated vapor emissions rate of the remaining feed organic COPCs in Column F is calculated in Cell F152. The resulting average value is then assigned in Column F to each of the feed organic COPCs without Tank Farm Average Ratios (Assumption 6.2.28). These adjusted results are then used to determine the unabated total emissions and abated vapor/total emissions for these COPCs.

7.2.4.2.3 Exceeded De Minimis Values

Due to the adjustments of PICs and feed organic COPCs with zero emissions, some of the adjusted COPCs have unabated total emissions exceeding the de minimis emissions limits for TAPs established in WAC 173-460-150 (Input 2.13), based on a comparison to the limits using the worksheet “*WAC 173-460-150*”.

The following table shows the adjusted feed organic COPCs with unabated total emissions exceeding the de minimis emissions limits.

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Table 7-26 Adjusted Feed Organic COPCs Exceeding De Minimis Values

CAS #	COPC	De minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Feed Organic COPCs - Total Unabated Emissions of COPC <i>i</i> , in lb/yr	Difference: Feed Organic COPC minus de minimis, in lb/yr
56-49-5	3-Methylcholanthrene	1.53E-03	1.17E+00	1.17E+00
3697-24-3	5-Methylchrysene	8.72E-03	1.17E+00	1.16E+00
602-87-9	5-Nitroacenaphthene	2.59E-01	1.17E+00	9.14E-01
60-35-5	Acetamide	4.80E-01	1.17E+00	6.93E-01
75-27-4	Bromodichloromethane	2.59E-01	1.17E+00	9.14E-01
72-55-9	DDE	9.88E-02	1.17E+00	1.07E+00
117-81-7	Di(2-ethylhexyl)phthalate	4.00E-01	1.17E+00	7.73E-01
226-36-8	Dibenz[a,h]acridine	8.72E-02	1.17E+00	1.09E+00
224-42-0	Dibenz[a,j]acridine	8.72E-02	1.17E+00	1.09E+00
192-65-4	Dibenzo[a,e]pyrene	8.72E-03	1.17E+00	1.16E+00
189-64-0	Dibenzo[a,h]pyrene	8.72E-04	1.17E+00	1.17E+00
189-55-9	Dibenzo[a,i]pyrene	8.72E-04	1.17E+00	1.17E+00
191-30-0	Dibenzo[a,l]pyrene	8.72E-04	1.17E+00	1.17E+00
193-39-5	Indeno[1,2,3-cd]pyrene	8.72E-02	1.17E+00	1.09E+00
10595-95-6	n-Nitroso-n-methylethylamine	1.53E-03	1.17E+00	1.17E+00
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	5.05E-07	1.70E-06	1.19E-06
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	2.52E-06	2.84E-06	3.21E-07

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7.3 Inorganic COPC Emissions

The inorganic COPC emissions estimate calculation Excel spreadsheet with the file name “*DFLAW Inorganic and PIC COPC Emissions Estimate.xlsx*” is included in Attachment C. The following section describes how the spreadsheet is used to estimate organic COPC emissions.

7.3.1 Feed Inorganic COPC Emissions

7.3.1.1 COPC Maximum Batch Masses, Mass Fractions, and Concentrations

The maximum batch mass fraction and concentration of each feed inorganic COPC is calculated using the Excel spreadsheet titled “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-27 “DFLAW Inorganic COPC Emissions Estimate.xlsx” Calculation of Maximum Batch Masses, Mass Fractions, and Concentrations

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Inorganic COPCs – Calc</i>	C5:C47	r_i = Tank farm ratio for COPC i , g COPC / g Na		Ref. 9.2
<i>Feed Inorganic COPCs – Calc</i>	S5	$n_{Na,max}$ = Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmols	Attachment G	Sodium amounts in each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Feed Inorganic COPCs – Calc</i>	S6	MW_{Na} = Molecular weight of sodium, in g/mol	Input 2.5	
<i>Feed Inorganic COPCs – Calc</i>	D5:D47	m_i = Maximum feed vector batch mass of COPC i , in g	Equation 51	For Hg (Cell D20) see Section 7.3.1.2.1
<i>Feed Inorganic COPCs – Calc</i>	S7	$V_{batch,avg}$ = Average total feed vector batch volume, in gal	Attachment G	Volumes of each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Feed Inorganic COPCs – Calc</i>	S8	$\rho_{batch,avg}$ = Average total vector batch density, in g/cc	Attachment G	Densities of each DFLAW feed batch from the bounding DFLAW Feed Vector provided in Ref. 9.2
<i>Feed Inorganic COPCs – Calc</i>	S9	$m_{batch,avg}$ = Average total feed vector batch mass, in g	Equation 9	
<i>Feed Inorganic COPCs – Calc</i>	E5:E47	x_i = Maximum feed vector batch mass fraction of COPC i	Equation 10	
<i>Feed Inorganic COPCs – Calc</i>	F5:F47	c_i = Maximum feed vector batch concentration of COPC i , in g/L	Equation 11	

7.3.1.2 Particle Phase Feed Inorganic COPC Emissions

The particle phase feed inorganic COPC emissions are calculated using the Excel spreadsheet titled “DFLAW Inorganic COPC Emissions Estimate.xlsx” shown in Attachment C . The following table describes how these values are calculated within the spreadsheet:

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Table 7-28 “DFLAW Organic and PIC COPC Emissions Estimate.xlsx” Particle Phase Feed Inorganic COPC Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Inorganic COPCs – Calc</i>	S10	$\bar{m}_{ves,vent}$ = Total mass flowrate of the DVP system except for evaporator, in lb/hr	Assumption 6.1.4	
<i>Feed Inorganic COPCs – Calc</i>	S11	EF_{ves} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.3	Assumption 6.2.3
<i>Feed Inorganic COPCs – Calc</i>	S12	$\bar{m}_{evap,vent}$ = Mass flowrate of the evaporator vent stream, in lb/hr	Assumption 6.1.4	
<i>Feed Inorganic COPCs – Calc</i>	S13	EF_{evap} = Entrainment factor for DEP vessels, in g entrained material / g air	Input 2.20	Assumption 6.2.30
<i>Feed Inorganic COPCs – Calc</i>	S14	$\bar{m}_{tot,entrained}$ = Total mass flowrate of entrained material, in g/min	Equation 12	
<i>Feed Inorganic COPCs – Calc</i>	H5:H47 (Except H11, H14, H26)	$\bar{m}_{i,entrained}$ = Entrained mass flowrate of COPC <i>i</i> , in g/min	Equation 31	Emissions of CS ₂ , CN, and NH ₃ are evaluated separately
<i>Feed Inorganic COPCs – Calc</i>	I5:I47 (Except I11, I14, I26)	$\bar{m}_{i,part,unabated}$ = Unabated particulate emissions of COPC <i>i</i> , in g/sec	Equation 32	Emissions of CS ₂ , CN, and NH ₃ are evaluated separately
<i>Feed Inorganic COPCs – Calc</i>	S15	$DF_{HEPA,primary}$ = Decontamination factor of primary HEPA filter	Assumption 6.2.10	
<i>Feed Inorganic COPCs – Calc</i>	S16	$DF_{HEPA,secondary}$ = Decontamination factor of secondary HEPA filter	Assumption 6.2.10	
<i>Feed Inorganic COPCs – Calc</i>	J5:J47 (Except J11, J14, J26)	$\bar{m}_{i,part,abated}$ = Abated particulate emissions of COPC <i>i</i> , in g/sec	Equation 33	Emissions of CS ₂ , CN, and NH ₃ are evaluated separately

7.3.1.2.1 Mercury

First the mass of Hg using Equation 51 is calculated.

$$m_{Hg} = r_{Hg} * n_{Na,max} * MW_{Na} * 1000 \frac{mol}{kmol} = 4.18E-5 \frac{g\ Hg}{g\ Na} * 3063.6\ kmol\ Na * 22.9898 \frac{g}{mol} * 1000 \frac{mol}{kmol}$$

$$m_{Hg} = 2.94E3\ g$$

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Next the mass of Hg at the ICD-30 limit is calculated using Equation 52.

$$m_{Hg,ICD30} = c_{Hg,ICD30} * n_{Na,max} * MW_{Hg} * 1000 \frac{mol}{kmol} = 1.4E-5 \frac{mol Hg}{mol Na} * 3063.6 kmol Na * 200.59 \frac{g}{mol} Hg * 1000 \frac{mol}{kmol}$$
$$m_{Hg,ICD30} = 8.60E3 g$$

Since $m_{Hg,ICD30}$ is greater than m_{Hg} , it will be used to estimate emissions through entrainment. The value for $m_{Hg,ICD30}$ is entered into Cell D20 of Excel spreadsheet “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*Feed Inorganic COPCs – Calc*” and the emissions of Hg through entrainment are calculated using the same method as other particle phase inorganic feed COPCs.

7.3.1.3 Vapor Phase Feed Inorganic COPC Emissions

Ammonia, carbon disulfide, and cyanide are emitted in the vapor phase (Assumption 6.2.21 and 6.2.16). As noted in Section 5.3.1.3, carbon disulfide is a feed organic COPC and its emissions will be reported with feed organic COPCs and not feed inorganic COPCs.

7.3.1.3.1 Carbon Disulfide, Ammonia, and Cyanide in the Feed Flush Line

The vapor phase feed inorganic COPC emissions are calculated using the Excel spreadsheet titled “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” shown in Attachment C . The following table describes how these values are calculated within the spreadsheet:

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Table 7-29 “DFLAW Inorganic COPC Emissions Estimate.xlsx” Vapor Phase Feed Inorganic COPC Emissions

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>Feed Inorganic COPCs – Calc</i>	S17	V_{flush} = Total volume of LAW feed line flush, in gal	Input 2.4, Assumption 6.1.3	
<i>Feed Inorganic COPCs – Calc</i>	S18	<i>Dilution Factor</i> = Flush dilution factor	Assumption 6.1.2	
<i>Feed Inorganic COPCs – Calc</i>	S19	$V_{residual\ feed}$ = Volume of residual feed in a LAW feed line flush, in L	Equation 16	
<i>Feed Inorganic COPCs – Calc</i>	S20	F_{flush} = Frequency of LAW feed line flush, in 1/hr	Assumption 6.1.3	
<i>Feed Inorganic COPCs – Calc</i>	L11, L14, L26	$\bar{m}_{i,flush}$ = Mass of COPC <i>i</i> flushed to DEP-VSL-0001 annually, in g/yr	Equation 17	
<i>Feed Inorganic COPCs – Calc</i>	M11, M14, M26	$\bar{m}_{i,vap,unabated}$ = Unabated vapor phase emissions of COPC <i>i</i> , in g/sec	Equation 30	
<i>Feed Inorganic COPCs – Calc</i>	N11, N14, N26	$\bar{m}_{i,vap,abated}$ = Abated vapor phase emissions of COPC <i>i</i> , in g/sec	Same as $\bar{m}_{i,vap,unabated}$	Assumption 6.2.10

7.3.1.3.2 Ammonia Emissions due to Caustic Scrubber Effluent

The vapor phase emissions due to NH₃ in the feed line flush are accounted for in Table 7-29 above with the cell locations associated with Row 26.

The vapor phase emissions from DEP-VSL-00004A/B and DEP-VSL-00005A/B due to NH₃ received from the caustic scrubber effluent are estimated using a Henry’s Law analysis. This analysis is shown in the Excel spreadsheet titled “DFLAW Inorganic COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

Table 7-30 “DFLAW Inorganic COPC Emissions Estimate.xlsx” NH₃ Emissions due to Caustic Scrubber Effluent

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>LVP21 NH3</i>	F4	$V_{LVP21,batch}$ = Batch transfer volume from LVP-TK-00001 to DEP-VSL-00004A/B, in gal	Input 2.15	
<i>LVP21 NH3</i>	F5	F_{LVP21} = Frequency of LVP-TK-00001 transfer, in 1/hr	Input 2.16	
<i>LVP21 NH3</i>	F6	$V_{LVP21,annual}$ = Annual volume transferred in LVP21, in L	Equation 53	Assumption 6.2.22

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Worksheet Title	Cell Location	Property	Calculation Method	Notes
LVP21 NH3	F7	ρ_{LVP21} = Density of LVP21, in g/L	Input 2.17	
LVP21 NH3	F8	x_{LVP21,NH_3} = Mass fraction of NH ₃ in LVP21	Attachment F, Table F-2	Assumption 6.1.16
LVP21 NH3	F9	m_{LVP21,NH_3} = Annual mass of NH ₃ in LVP21, in g	Equation 54	
LVP21 NH3	F10	$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm	Assumption 6.1.7	
LVP21 NH3	F11	CF = Evaporator volumetric concentration factor	Assumption 6.1.17	
LVP21 NH3	F12	$V_{DEPVSL4,annual}$ = Annual volume received in DEP-VSL-00004A/B, in gal	Equation 55	
LVP21 NH3	F13	c_{NH_3} = Concentration of NH ₃ in DEP-VSL-00004A/B, in g/L	Equation 56	Assumption 6.1.18
LVP21 NH3	F14	k'_{H,NH_3} = Henry's Law constant for NH ₃ , in atm*m ³ /mol	Input 2.18	
LVP21 NH3	F15	MW_{NH_3} = Molecular weight of NH ₃ , in g/mol	Input 2.9	
LVP21 NH3	F16	P = Vessel operating pressure, in atm	Assumption 6.1.10	
LVP21 NH3	F17	y_{NH_3} = Mole fraction of NH ₃ in the vapor phase	Equation 44	
LVP21 NH3	F18	\bar{m}_{vent} = Mass flowrate of the vessel vent streams from DEP-VSL-00004A/B and DEP-VSL-00005A/B, in lb/hr	Assumption 6.1.19	
LVP21 NH3	F19	MW_{air} = Average molecular weight of air, in g/mol	Input 2.8	
LVP21 NH3	F20	$\bar{m}_{vapor,vent,NH_3}$ = Vapor phase mass flow rate of NH ₃ in vessel vent streams from DEP-VSL-00004A/B and DEP-VSL-00005A/B, in g/sec	Equation 45	

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Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>LVP21 NH3</i>	F21	$\bar{m}_{NH_3,flush,unabated}$ = Unabated vapor phase emissions of NH ₃ in feed line flush, in g/sec	Equation 30	Value calculated in worksheet <i>Feed Organic COPCs – Calc Cell M26</i>
<i>LVP21 NH3</i>	F22	$\bar{m}_{NH_3,tot,unabated}$ = Total unabated emissions of NH ₃ , in g/sec	Equation 57	This value will be reported in the results for NH ₃ emissions
<i>LVP21 NH3</i>	F23	$\bar{m}_{NH_3,tot,abated}$ = Total abated emissions of NH ₃ , in g/sec	Same as $\bar{m}_{NH_3,tot,unabated}$	Assumption 6.2.10 This value will be reported in the results for NH ₃ emissions

7.3.1.3.3 Dimethyl Mercury

Dimethyl Mercury [(CH₃)₂Hg] has the potential to form in WTP waste streams due to the reaction between mercury and organic species (Ref. 9.15, Section 4.1).

7.3.1.3.3.1 Mercury Concentrations

The maximum mercury concentrations in each vessel are calculated using the Excel spreadsheet titled “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-31 “DFLAW Inorganic COPC Emissions Estimate.xlsx” Mercury Concentrations

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>DMHg</i>	S4	$c_{Hg,feed}$ = Maximum feed vector batch concentration of Hg, in g/L	Equation 11	
<i>DMHg</i>	S5	$V_{residual\ feed}$ = Volume of residual feed in a LAW feed line flush, in L	Equation 16	
<i>DMHg</i>	S6	V_{flush} = Total volume of LAW feed line flush, in gal	Input 2.4, Assumption 6.1.3	
<i>DMHg</i>	C5, C6	$c_{Hg,flush}$ = Concentration of Hg in feed line flush to DEP-VSL-00001, in g/L	Equation 58	Assumption 6.1.20 Concentration of DEP-VSL-00001 and DEP-VSL-00002
<i>DMHg</i>	S7	$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm	Assumption 6.1.7	
<i>DMHg</i>	S8	$MDR_{Evap,Hg}$ = Mass distribution ratio of Hg in evaporator	Assumption 6.1.13	
<i>DMHg</i>	S9	CF = Evaporator volumetric concentration factor	Assumption 6.1.17	
<i>DMHg</i>	C7, C8	$c_{Hg,conc}$ = Concentration of Hg in evaporator concentrate, in g/L	Equation 59	Concentration of DEP-EVAP-00001 and DEP-VSL-00003A/B/C
<i>DMHg</i>	C9, C10	$c_{Hg,cond}$ = Concentration of Hg in evaporator condensate, in g/L	Equation 60	Assumption 6.1.21 Concentration of DEP-VSL-00004A/B and DEP-VSL-00005A/B

7.3.1.3.3.2 Vessel Operating Temperatures

The DEP vessel nominal operating temperatures are used in the Excel spreadsheet titled “DFLAW Inorganic COPC Emissions Estimate.xlsx” shown in Attachment C. The following table describes how these values are used within the spreadsheet:

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Table 7-32 “DFLAW Inorganic COPC Emissions Estimate.xlsx” Vessel Temperatures

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>DMHg</i>	D5:D10	T_j = Vessel j Nominal Temperature, in °F	Assumptions 6.1.22 through 6.1.27	
<i>DMHg</i>	E5:E10	T_j = Vessel j Nominal Temperature, in K	Convert °F to K	

7.3.1.3.3.3 Vessel Residence Time

The vessel residence times are calculated using the Excel spreadsheet titled “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

Table 7-33 “DFLAW Inorganic COPC Emissions Estimate.xlsx” Mercury Concentrations

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>DMHg</i>	F5:F10, except F7	CT_j = Vessel j batch cycle time, in hr	Assumption 6.1.28	
<i>DMHg</i>	G5:G10	N_j = Quantity of vessel j		e.g. $N_{DEP-VSL-4} = 2$
<i>DMHg</i>	H5:H10, except H7	RT_j = Residence time for vessel j , in hr	Equation 61	
<i>DMHg</i>	S10	$V_{evap,recirc}$ = Volume of DEP evaporator recirculation loop, in gal	Assumption 6.1.29	
<i>DMHg</i>	S7	$V_{evap,feed}$ = Volumetric flowrate of DEP evaporator feed stream, in gpm	Assumption 6.1.7	
<i>DMHg</i>	H7	RT_{evap} = Residence time for evaporator, in hr	Equation 62	

7.3.1.3.3.4 Rate of Dimethyl Mercury Formation

The formation and emission rates of dimethyl mercury are calculated using the Excel spreadsheet titled “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” shown in Attachment C. The following table describes how these values are calculated within the spreadsheet:

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Table 7-34 “DFLAW Inorganic COPC Emissions Estimate.xlsx” Dimethyl Mercury Formation and Emission

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>DMHg</i>	I5:I10	k_j = Rate constant for vessel j , in s^{-1}	Equation 63	
<i>DMHg</i>	J5:J10	$c_{DMHg,j}$ = Concentration of dimethyl mercury in vessel j , in g/L	Equation 64	
<i>DMHg</i>	K5:K10	$V_{batch,j}$ = Vessel j batch volume, in gal	Assumption 6.1.30	$V_{batch,evap} = V_{batch,DEP-VSL-3}$
<i>DMHg</i>	L5:L10	\bar{V}_j = Annual vessel j throughput, in L	Equation 65	
<i>DMHg</i>	M5:M10	$\bar{m}_{DMHg,unabated,j}$ = Unabated vapor phase emissions of dimethyl mercury from vessel j , in g/sec	Equation 66	
<i>DMHg</i>	M11	$\bar{m}_{DMHg,unabated,tot}$ = Total unabated vapor phase emissions of dimethyl mercury from vessel j , in g/sec	Equation 67	
<i>DMHg</i>	N5:N10	$\bar{m}_{DMHg,abated,j}$ = Abated vapor phase emissions of dimethyl mercury from vessel j , in g/sec	Same as $\bar{m}_{DMHg,unabated,j}$	Assumption 6.2.10 This value will be reported in the results for dimethyl mercury emissions
<i>DMHg</i>	N11	$\bar{m}_{DMHg,abated,tot}$ = Total abated vapor phase emissions of dimethyl mercury from vessel j , in g/sec	Same as $\bar{m}_{DMHg,unabated,tot}$	Assumption 6.2.10 This value will be reported in the results for dimethyl mercury emissions

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7.3.2 Stack Inorganic COPC Emissions

Stack inorganic COPCs, except for particulate matter and methyl mercury, are gases or acids that are mainly produced during chemical reactions or thermal decomposition. These COPCs are:

Nitrogen dioxide
Carbon dioxide
Carbon monoxide
Ozone
Sulfur dioxide
Hydrogen chloride
Hydrogen Fluoride
Fluorine gas
Chlorine gas

The main source for these COPCs at WTP is the LAW and HLW melters. For example, in the existing WTP emissions estimate (Ref. 9.14, Table 18) the only streams with emissions of NO₂, CO, SO₂, HCl, and HF are the LAW and HLW offgas streams. Note that CO₂, O₃, F₂, and Cl₂ were not included in the existing WTP emissions estimate. It is assumed that there will not be the necessary thermal or kinetic conditions in the DEP system to produce significant amounts of the stack inorganic COPCs (Assumption 6.1.31). Therefore emissions of these COPCs are zero.

Monomethyl mercury is assumed to exist primarily in the liquid phase at WTP and its emissions are therefore grouped with the overall mercury emissions calculated in Section 7.3.1.2.1 (Assumption 6.2.25).

Total particulate matter emissions are the sum of the results for particulate emissions of radionuclides, feed organics, PICs, and feed inorganics. The total particulate emissions are reported in the “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*Inorganic Summary Table*” shown in Attachment C.

Total unabated particulate emissions of feed inorganic COPCs are the sum of Column I ($\bar{m}_{i,part,unabated}$) in the “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*Feed Inorganic COPCs - Calc*”. Total abated particulate emissions of inorganic COPCs are the sum of Column J ($\bar{m}_{i,abated}$) in the “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*Feed Inorganic COPCs - Calc*”.

Total unabated particulate emissions of radionuclide COPCs on a mass basis are the sum of Column K ($\bar{m}_{i,entrained}$) in the “*DFLAW Radionuclide COPC Emissions Estimate.xlsx*” Worksheet “*Radionuclide COPCs - Calc*”. Total abated particulate emissions of radionuclide COPCs on a mass basis are the total unabated particulate emissions divided by $DF_{HEPA,primary}$ and $DF_{HEPA,secondary}$ (similar to Equation 33).

Total unabated particulate emissions of feed organic COPCs are the sum of Column G ($\bar{m}_{i,part,unabated}$) in the “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Worksheet “*Organic Summary Table*”. Total abated particulate emissions of inorganic COPCs are the sum of Column K ($\bar{m}_{i,part,abated}$) in the “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*Organic Summary Table*”.

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Total unabated particulate emissions of PIC COPCs are the sum of Column E ($\bar{m}_{i,part,unabated}$) in the “*DFLAW Organic and PIC COPC Emissions Estimate.xlsx*” Worksheet “*PIC Summary Table*”. Total abated particulate emissions of inorganic COPCs are the sum of Column F ($\bar{m}_{i,part,abated}$) in the “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*PIC Summary Table*”.

7.3.3 Inorganic COPC Summary and Comparison to De Minimis Emissions Limits

The results from Sections 7.3.1 and 7.3.2 are summarized in “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” Worksheet “*Inorganic Summary Table*” shown in Attachment C.

The total unabated emissions values are compared to de minimis emissions limits for TAPs established in WAC 173-460-150 (Input 2.13), using the worksheet “*WAC 173-460-150*”.

Table 7-35 “*DFLAW Inorganic COPC Emissions Estimate.xlsx*” De Minimis Value Comparison

Worksheet Title	Cell Location	Property	Calculation Method	Notes
<i>WAC 173-460-150</i>	G5:G400	$\bar{m}_{i,dm}$ = de minimis emissions limit for COPC <i>i</i> , lb/averaging period	Input 2.13	
<i>WAC 173-460-150</i>	I5:I400	$\bar{m}_{i,dm\ standard}$ = de minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Equation 38	
<i>WAC 173-460-150</i>	J5:J400	$\bar{m}_{i,total,unabated}$ Inorganic COPCs – Total Unabated Emissions of COPC <i>i</i> , in lb/yr	Vlookup of Column D in “ <i>Inorganic Summary Table</i> ” worksheet	Converted from g/sec to lb/yr
<i>WAC 173-460-150</i>	L5:L400	Difference: Feed Inorganic COPC minus de minimis, in lb/yr	Column J minus Column I	

The comparison in worksheet “*WAC 173-460-150*” showed that ammonia, cadmium, dimethyl mercury, and chromium (VI) exceed their de minimis values.

Ammonia was already evaluated using a Henry’s Law method (Section 7.3.1.3.2) so it will not be reevaluated using Henry’s Law like the feed organic COPCs in Section 7.2.4.1. Cadmium will not be reevaluated using Henry’s Law because it is nonvolatile and emitted through entrainment. Dimethyl mercury will also not be reevaluated, because the de minimis value of 3.65E-97 lb/yr is essentially zero and a revaluation will not reduce the emissions to below that limit.

Chromium (VI) is listed as a TAP in WAC 173-460-150, however only generic total chromium (without a specified oxidation state) is evaluated as a COPC in the emissions estimate. In order to provide a bounding estimate for chromium (VI) emissions to compare to the de minimis value, it is assumed that all chromium emitted is chromium (VI) (Assumption 6.2.29). Therefore, the total unabated emissions estimate for chromium is assigned to chromium (VI) and is shown in the table below as exceeding the de minimis value.

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Table 7-36 Inorganic COPCs that Exceed De Minimis Value

CAS #	COPC	De minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Feed Organic COPCs - Total Unabated Emissions of COPC <i>i</i> , in lb/yr	Difference: Feed Organic COPC minus de minimis, in lb/yr
7664-41-7	Ammonia	1.70E+02	7.00E+03	6.83E+03
7440-43-9	Cadmium & Compounds	2.28E-03	2.82E-02	2.59E-02
18540-29-9	Chromium (VI)	6.40E-05	1.00E+00	1.00E+00
593-74-8	Dimethyl mercury	3.65E-97	3.67E-02	3.67E-02

8 Results and Conclusions

8.1 Discussion of Margin and Conservatism

In the absence of DFLAW-specific emissions estimates using the APPS model, this calculation uses a series of simplifying assumptions to provide a conservative estimate of the emissions of radionuclides from the DVP and ACV exhaust systems. These results will be verified by the results from the DFLAW-specific APPS model runs when they become available. The steady-state model will provide a stream-by-stream mass balance to estimate the emissions.

Typically there is no margin included in process calculations. This calculation does apply conservatism in several places in order to bound the possible results from the DFLAW-specific APPS model runs. The main conservatisms included in this calculation are the following:

- Use of the Tank Farm Average ratios and DFLAW Bounding Feed Vector to estimate COPC inventory received (Assumptions 6.2.1 and 6.2.2)
- It is conservative and bounding to assume the mass fractions of COPCs emitted by entrainment do not decrease from the maximum expected feed value throughout the DEP system (Assumption 6.1.1, Assumption 6.1.33).
- The nominal entrainment factor for free-falling aqueous solution (4E-5) is a conservative and representative for estimating particulate emissions from the DEP vessels, except for the evaporator (Assumption 6.2.3).
- The entrainment factor prescribed in WAC 246-247-030 (21)(a)(ii) for liquids and particulate solids (1E-3) is conservative and bounding for the estimation of particulate emissions from the DEP evaporator (Assumption 6.2.30).
- The dilution factor of $\frac{1}{30}$ is considered a conservative value for the approximation of the amount of residual feed flushed to DEP-VSL-00001 (Assumption 6.1.2).
- It is assumed that all ^{14}C received in the EMF is emitted as it is processed through the DEP system (Assumption 6.2.4).
- It is assumed that the entire vapor fraction of each feed organic COPC received in DEP-VSL-00001 annually is emitted to the DEP vessel ventilation system as it is processed through the DEP system (Assumption 6.2.16).

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- Feed transfers from the LAWPS to LAW are assumed to occur continuously without a break between transfers (i.e. a transfer begins immediately after the preceding one is finished) (Assumption 6.2.5).
- The two month duration of release used from Ref. 9.13 to estimate ACV Exhaust system emissions is conservative and bounding (Assumption 6.2.11).
- Particle or particle-bound PIC COPCs that do not have generation rates reported in Ref. 9.15, Table 3 are assigned a generation rate equal to the maximum generation rate for a particle or particle-bound PIC COPC that does have a generation rate reported in Ref. 9.15, Table 3 (Assumption 6.2.17)
- For ammonia emissions, the transfers from LVP-TK-00001 to DEP-VSL-00004A/B are assumed to occur continuously at the specified frequency and batch volume (Assumption 6.2.22).
- Average feed vector batch volumes, densities, and masses are used in Equation 9 through Equation 11 to calculate conservative values for maximum feed vector batch mass fractions, x_i , and concentrations, c_i . (Assumption 6.1.34).
- In order to assign a bounding emissions estimate greater than 0 g/sec for the subset of PIC COPCs that have a vapor phase type, these COPCs are assumed to be emitted at the average non-zero unabated particulate emissions rate for PIC COPCs (Assumption 6.2.27).
- In order to assign a bounding emissions estimate greater than 0 g/sec for the subset of feed organic COPCs without Tank Farms Average Ratios, these COPCs are assumed to be emitted at the average unabated vapor emissions rate for feed organic COPCs with Tank Farms Average Ratios (Assumption 6.2.28).
- In order to compare estimated chromium (VI) emissions to the de minimis limit for chromium (VI), it is assumed that all chromium emitted is chromium (VI) (Assumption 6.2.29).

8.2 Emissions Summary

The results for the emissions of radionuclide COPCs are summarized in Table 8-8 summarizes the COPCs with unabated emissions estimates that exceed the WAC de minimis value.

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Table 8-1 and Table 8-2. APQs for radionuclide COPCs are summarized in Table 8-3.

The results for the emissions of feed organic and PIC COPCs are summarized in Table 8-4 and Table 8-5 respectively.

The results for the emissions of inorganic COPCs are summarized in Table 8-6 and Table 8-7 .

Table 8-8 summarizes the COPCs with unabated emissions estimates that exceed the WAC de minimis value.

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Table 8-1 – Radionuclide COPC Emissions from DVP System

CAS #	COPC	Unabated Stream		Abated Stream	
		DEP15		DEP18	
		DEP Vessel Vent		DEP Vessel Vent	
		Ci/yr	% Contribution	Ci/yr	% Contribution
13967-48-1	106Ru	9.19E-06	0%	4.60E-11	0%
378253-44-2	113mCd	2.99E-03	0%	1.50E-08	0%
14234-35-6	125Sb	3.18E-03	0%	1.59E-08	0%
15832-50-5	126Sn	3.01E-04	0%	1.50E-09	0%
15046-84-1	129I	2.27E-05	0%	1.13E-10	0%
13967-70-9	134Cs	5.49E-04	0%	2.75E-09	0%
10045-97-3	137Cs	5.27E-02	1%	2.64E-07	0%
378253-40-8	137mBa	4.98E-02	1%	2.49E-07	0%
14762-75-5	14C (Note 1)	1.82E-01	3%	1.82E-01	99%
15715-94-3	151Sm	2.75E+00	38%	1.37E-05	0%
14683-23-9	152Eu	6.97E-04	0%	3.49E-09	0%
15585-10-1	154Eu	3.70E-03	0%	1.85E-08	0%
14391-16-3	155Eu	1.96E-02	0%	9.82E-08	0%
13982-63-3	226Ra	7.64E-09	0%	3.82E-14	0%
14952-40-0	227Ac	2.92E-06	0%	1.46E-11	0%
15262-20-1	228Ra	5.11E-06	0%	2.56E-11	0%
15594-54-4	229Th	1.05E-06	0%	5.26E-12	0%
14331-85-2	231Pa	3.92E-06	0%	1.96E-11	0%
7440-29-1	232Th	5.11E-06	0%	2.56E-11	0%
14158-29-3	232U	6.49E-06	0%	3.24E-11	0%
13968-55-3	233U	3.29E-05	0%	1.64E-10	0%
13966-29-5	234U	1.82E-04	0%	9.10E-10	0%
15117-96-1	235U	3.49E-07	0%	1.75E-12	0%
13982-70-2	236U	5.00E-06	0%	2.50E-11	0%
13994-20-2	237Np	1.12E-05	0%	5.62E-11	0%
13981-16-3	238Pu	2.58E-04	0%	1.29E-09	0%
7440-61-1R	238U	1.66E-04	0%	8.28E-10	0%
15117-48-3	239Pu	4.84E-03	0%	2.42E-08	0%
14119-33-6	240Pu	1.06E-03	0%	5.31E-09	0%
14596-10-2	241Am	1.53E-02	0%	7.67E-08	0%
14119-32-5	241Pu	6.45E-02	1%	3.22E-07	0%
15510-73-3	242Cm	9.39E-05	0%	4.70E-10	0%
13982-10-0	242Pu	8.11E-08	0%	4.05E-13	0%
14993-75-0	243Am	7.09E-06	0%	3.55E-11	0%
15757-87-6	243Cm	1.33E-06	0%	6.63E-12	0%
13981-15-2	244Cm	2.92E-05	0%	1.46E-10	0%
10028-17-8	3H (Note 1)	2.17E-03	0%	2.17E-03	1%
14336-70-0	59Ni	1.24E-03	0%	6.18E-09	0%
10198-40-0	60Co	2.26E-04	0%	1.13E-09	0%
13981-37-8	63Ni	1.10E-01	2%	5.52E-07	0%
15758-45-9	79Se	1.10E-04	0%	5.52E-10	0%
10098-97-2	90Sr	1.97E+00	27%	9.87E-06	0%
10098-91-6	90Y	1.97E+00	27%	9.87E-06	0%
378782-82-2	93mNb	2.44E-03	0%	1.22E-08	0%
15751-77-6	93Zr	2.87E-03	0%	1.44E-08	0%
14133-76-7	99Tc	2.03E-02	0%	1.02E-07	0%
	Total	7.24E+00	100%	1.85E-01	100%

Note 1: COPC emitted in the vapor phase

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Table 8-2 - Radionuclide COPC Emissions from ACV Exhaust System

CAS #	COPC	Unabated Stream		Abated Stream		Abated Stream	
		ACV Exhaust		ACV Exhaust (single-stage HEPA)		ACV Exhaust (dual-stage HEPA)	
		Ci/yr	% Contribution	Ci/yr	% Contribution	Ci/yr	% Contribution
13967-48-1	106Ru	1.53E-06	0%	7.66E-10	0%	7.66E-12	0%
378253-44-2	113mCd	4.98E-04	0%	2.49E-07	0%	2.49E-09	0%
14234-35-6	125Sb	5.30E-04	0%	2.65E-07	0%	2.65E-09	0%
15832-50-5	126Sn	5.01E-05	0%	2.51E-08	0%	2.51E-10	0%
15046-84-1	129I	3.78E-06	0%	1.89E-09	0%	1.89E-11	0%
13967-70-9	134Cs	9.15E-05	0%	4.58E-08	0%	4.58E-10	0%
10045-97-3	137Cs	8.79E-03	1%	4.39E-06	0%	4.39E-08	0%
378253-40-8	137mBa	8.30E-03	1%	4.15E-06	0%	4.15E-08	0%
14762-75-5	14C (Note 1)	3.04E-02	3%	3.04E-02	97%	3.04E-02	99%
15715-94-3	151Sm	4.58E-01	38%	2.29E-04	1%	2.29E-06	0%
14683-23-9	152Eu	1.16E-04	0%	5.81E-08	0%	5.81E-10	0%
15585-10-1	154Eu	6.17E-04	0%	3.08E-07	0%	3.08E-09	0%
14391-16-3	155Eu	3.27E-03	0%	1.64E-06	0%	1.64E-08	0%
13982-63-3	226Ra	1.27E-09	0%	6.37E-13	0%	6.37E-15	0%
14952-40-0	227Ac	4.87E-07	0%	2.44E-10	0%	2.44E-12	0%
15262-20-1	228Ra	8.52E-07	0%	4.26E-10	0%	4.26E-12	0%
15594-54-4	229Th	1.75E-07	0%	8.77E-11	0%	8.77E-13	0%
14331-85-2	231Pa	6.53E-07	0%	3.27E-10	0%	3.27E-12	0%
7440-29-1	232Th	8.52E-07	0%	4.26E-10	0%	4.26E-12	0%
14158-29-3	232U	1.08E-06	0%	5.41E-10	0%	5.41E-12	0%
13968-55-3	233U	5.48E-06	0%	2.74E-09	0%	2.74E-11	0%
13966-29-5	234U	3.03E-05	0%	1.52E-08	0%	1.52E-10	0%
15117-96-1	235U	5.82E-08	0%	2.91E-11	0%	2.91E-13	0%
13982-70-2	236U	8.33E-07	0%	4.17E-10	0%	4.17E-12	0%
13994-20-2	237Np	1.87E-06	0%	9.36E-10	0%	9.36E-12	0%
13981-16-3	238Pu	4.31E-05	0%	2.15E-08	0%	2.15E-10	0%
7440-61-1R	238U	2.76E-05	0%	1.38E-08	0%	1.38E-10	0%
15117-48-3	239Pu	8.07E-04	0%	4.04E-07	0%	4.04E-09	0%
14119-33-6	240Pu	1.77E-04	0%	8.85E-08	0%	8.85E-10	0%
14596-10-2	241Am	2.56E-03	0%	1.28E-06	0%	1.28E-08	0%
14119-32-5	241Pu	1.07E-02	1%	5.37E-06	0%	5.37E-08	0%
15510-73-3	242Cm	1.57E-05	0%	7.83E-09	0%	7.83E-11	0%
13982-10-0	242Pu	1.35E-08	0%	6.75E-12	0%	6.75E-14	0%
14993-75-0	243Am	1.18E-06	0%	5.91E-10	0%	5.91E-12	0%
15757-87-6	243Cm	2.21E-07	0%	1.11E-10	0%	1.11E-12	0%
13981-15-2	244Cm	4.87E-06	0%	2.44E-09	0%	2.44E-11	0%
10028-17-8	3H (Note 1)	3.62E-04	0%	3.62E-04	1%	3.62E-04	1%
14336-70-0	59Ni	2.06E-04	0%	1.03E-07	0%	1.03E-09	0%
10198-40-0	60Co	3.77E-05	0%	1.88E-08	0%	1.88E-10	0%
13981-37-8	63Ni	1.84E-02	2%	9.20E-06	0%	9.20E-08	0%
15758-45-9	79Se	1.84E-05	0%	9.21E-09	0%	9.21E-11	0%
10098-97-2	90Sr	3.29E-01	27%	1.64E-04	1%	1.64E-06	0%
10098-91-6	90Y	3.29E-01	27%	1.64E-04	1%	1.64E-06	0%
378782-82-2	93mNb	4.07E-04	0%	2.03E-07	0%	2.03E-09	0%
15751-77-6	93Zr	4.79E-04	0%	2.39E-07	0%	2.39E-09	0%
14133-76-7	99Tc	3.39E-03	0%	1.70E-06	0%	1.70E-08	0%
	Total	1.21E+00	100%	3.13E-02	100%	3.08E-02	100%

Note 1: COPC emitted in the vapor phase

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

CALC NO.: 24590-BOF-M4C-DEP-00001

SHEET REV: B

SHEET NO.: 109

BY: William Hix
DATE: 6/6/2016

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

Table 8-3 – Radionuclide COPC Annual Possession Quantities

CAS #	COPC	Annual Possession Quantities
		DEP
		Ci/yr
13967-48-1	106Ru	8.91E-01
378253-44-2	113mCd	2.90E+02
14234-35-6	125Sb	3.08E+02
15832-50-5	126Sn	2.92E+01
15046-84-1	129I	2.20E+00
13967-70-9	134Cs	5.32E+01
10045-97-3	137Cs	5.11E+03
378253-40-8	137mBa	4.83E+03
14762-75-5	14C	1.82E-01
15715-94-3	151Sm	2.67E+05
14683-23-9	152Eu	6.76E+01
15585-10-1	154Eu	3.59E+02
14391-16-3	155Eu	1.90E+03
13982-63-3	226Ra	7.41E-04
14952-40-0	227Ac	2.83E-01
15262-20-1	228Ra	4.96E-01
15594-54-4	229Th	1.02E-01
14331-85-2	231Pa	3.80E-01
7440-29-1	232Th	4.96E-01
14158-29-3	232U	6.29E-01
13968-55-3	233U	3.19E+00
13966-29-5	234U	1.76E+01
15117-96-1	235U	3.39E-02
13982-70-2	236U	4.85E-01
13994-20-2	237Np	1.09E+00
13981-16-3	238Pu	2.51E+01
7440-61-1R	238U	1.61E+01
15117-48-3	239Pu	4.70E+02
14119-33-6	240Pu	1.03E+02
14596-10-2	241Am	1.49E+03
14119-32-5	241Pu	6.25E+03
15510-73-3	242Cm	9.11E+00
13982-10-0	242Pu	7.86E-03
14993-75-0	243Am	6.88E-01
15757-87-6	243Cm	1.29E-01
13981-15-2	244Cm	2.84E+00
10028-17-8	3H	9.33E-01
14336-70-0	59Ni	1.20E+02
10198-40-0	60Co	2.19E+01
13981-37-8	63Ni	1.07E+04
15758-45-9	79Se	1.07E+01
10098-97-2	90Sr	1.91E+05
10098-91-6	90Y	1.91E+05
378782-82-2	93mNb	2.37E+02
15751-77-6	93Zr	2.78E+02
14133-76-7	99Tc	1.97E+03
	Total	6.84E+05

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

CALC NO.: 24590-BOF-M4C-DEP-00001

SHEET REV: B

SHEET NO.: 110

BY: William Hix

DATE: 6/6/2016

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

Table 8-4 – Feed Organic COPC Emissions from DVP System

CAS #	COPC	Feed or Feed/PIC (Note 1)	Unabated Streams			Abated Streams		
			DEP15			DEP18		
			DEP Vessel Vent			DEP Vessel Vent		
			Vapor	Particulate	Total	Vapor	Particulate	Total
			g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
630-20-6	1,1,1,2-Tetrachloroethane	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
71-55-6	1,1,1-Trichloroethane	Feed	1.98E-10	0.00E+00	1.98E-10	1.98E-10	0.00E+00	1.98E-10
79-34-5	1,1,2,2-Tetrachloroethane	Feed	1.88E-10	0.00E+00	1.88E-10	1.88E-10	0.00E+00	1.88E-10
127-18-4	Tetrachloroethene	Feed	1.95E-10	0.00E+00	1.95E-10	1.95E-10	0.00E+00	1.95E-10
79-00-5	1,1,2-Trichloroethane	Feed	1.87E-10	0.00E+00	1.87E-10	1.87E-10	0.00E+00	1.87E-10
79-01-6	Trichloroethene	Feed/PIC	2.13E-10	4.31E-10 (Note 5)	6.44E-10	2.13E-10	2.15E-15	2.13E-10
92-52-4	Biphenyl	Feed	3.73E-08	0.00E+00	3.73E-08	3.73E-08	0.00E+00	3.73E-08
75-34-3	1,1-Dichloroethane	Feed	1.60E-10	0.00E+00	1.60E-10	1.60E-10	0.00E+00	1.60E-10
75-35-4	1,1-Dichloroethene	Feed	2.52E-10	0.00E+00	2.52E-10	2.52E-10	0.00E+00	2.52E-10
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	Feed	4.89E-10	0.00E+00	4.89E-10	4.89E-10	0.00E+00	4.89E-10
120-82-1	1,2,4-Trichlorobenzene	Feed	1.18E-08	0.00E+00	1.18E-08	1.18E-08	0.00E+00	1.18E-08
95-50-1	1,2-Dichlorobenzene	Feed	1.54E-07	0.00E+00	1.54E-07	1.54E-07	0.00E+00	1.54E-07
107-06-2	1,2-Dichloroethane	Feed/PIC	1.87E-10	4.31E-10 (Note 5)	6.18E-10	1.87E-10	2.15E-15	1.87E-10
78-87-5	1,2-Dichloropropane	Feed	1.60E-10	0.00E+00	1.60E-10	1.60E-10	0.00E+00	1.60E-10
106-88-7	1,2-Epoxybutane	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
156-60-5	1,2-trans-Dichloroethene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
106-99-0	1,3-Butadiene	Feed	5.37E-09	0.00E+00	5.37E-09	5.37E-09	0.00E+00	5.37E-09
541-73-1	1,3-Dichlorobenzene	Feed	7.76E-09	0.00E+00	7.76E-09	7.76E-09	0.00E+00	7.76E-09
106-46-7	1,4-Dichlorobenzene	Feed/PIC	1.01E-07	4.31E-10 (Note 5)	1.02E-07	1.01E-07	2.15E-15	1.01E-07
123-91-1	1,4-Dioxane	Feed	5.91E-09	0.00E+00	5.91E-09	5.91E-09	0.00E+00	5.91E-09
75-01-4	Vinyl chloride	Feed	4.05E-10	0.00E+00	4.05E-10	4.05E-10	0.00E+00	4.05E-10
58-90-2	2,3,4,6-Tetrachlorophenol	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
95-95-4	2,4,5-Trichlorophenol	Feed	4.87E-05	0.00E+00	4.87E-05	4.87E-05	0.00E+00	4.87E-05
88-06-2	2,4,6-Trichlorophenol	Feed	1.68E-06 (Note 2)	0.00E+00	1.68E-06	1.68E-06	0.00E+00	1.68E-06
120-83-2	2,4-Dichlorophenol	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
121-14-2	2,4-Dinitrotoluene	Feed/PIC	2.27E-08 (Note 2)	1.32E-10	2.29E-08	2.27E-08	6.62E-16	2.27E-08
128-37-0	2,6-Bis(1,1-dimethylethyl)-4-methylphenol	Feed	2.83E-07	0.00E+00	2.83E-07	2.83E-07	0.00E+00	2.83E-07
78-93-3	2-Butanone	Feed/PIC	6.40E-08	4.31E-10 (Note 5)	6.44E-08	6.40E-08	2.15E-15	6.40E-08
111-76-2	2-Butoxyethanol	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
91-58-7	2-Chloronaphthalene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
95-57-8	2-Chlorophenol	Feed	5.36E-05	0.00E+00	5.36E-05	5.36E-05	0.00E+00	5.36E-05
110-80-5	2-Ethoxyethanol	Feed	1.13E-04	0.00E+00	1.13E-04	1.13E-04	0.00E+00	1.13E-04
104-76-7	2-Ethyl-1-hexanol	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
591-78-6	2-Hexanone	Feed	2.55E-08	0.00E+00	2.55E-08	2.55E-08	0.00E+00	2.55E-08
126-98-7	2-Methyl-2-propenenitrile	Feed	5.91E-09	0.00E+00	5.91E-09	5.91E-09	0.00E+00	5.91E-09
78-83-1	Isobutanol	Feed	2.77E-04	0.00E+00	2.77E-04	2.77E-04	0.00E+00	2.77E-04
88-75-5	2-Nitrophenol	Feed/PIC	5.04E-05	4.31E-10 (Note 5)	5.04E-05	5.04E-05	2.15E-15	5.04E-05
79-46-9	2-Nitropropane	Feed	3.95E-08	0.00E+00	3.95E-08	3.95E-08	0.00E+00	3.95E-08
67-64-1	Acetone	Feed/PIC	2.80E-07	4.31E-10 (Note 5)	2.81E-07	2.80E-07	2.15E-15	2.80E-07
79-10-7	2-Propenoic acid	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
67-63-0	Isopropyl alcohol	Feed	1.65E-08	0.00E+00	1.65E-08	1.65E-08	0.00E+00	1.65E-08
107-05-1	3-Chloropropene	Feed	5.91E-10	0.00E+00	5.91E-10	5.91E-10	0.00E+00	5.91E-10
589-38-8	3-Hexanone	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
56-49-5	3-Methylcholanthrene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
72-55-9	4,4-DDE	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
101-55-3	4-Bromophenylphenyl ether	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
59-50-7	4-Chloro-3-methylphenol	Feed	5.19E-05	0.00E+00	5.19E-05	5.19E-05	0.00E+00	5.19E-05
100-40-3	4-Ethenylcyclohexene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
108-10-1	Hexone	Feed	2.09E-09	0.00E+00	2.09E-09	2.09E-09	0.00E+00	2.09E-09
3697-24-3	5-Methylchrysene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
602-87-9	5-Nitroacenaphthene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

CALC NO.: 24590-BOF-M4C-DEP-00001

SHEET REV: B

SHEET NO.: 111

BY: William Hix

DATE: 6/6/2016

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

CAS #	COPC	Feed or Feed/PIC (Note 1)	Unabated Streams			Abated Streams		
			DEP15			DEP18		
			DEP Vessel Vent			DEP Vessel Vent		
			Vapor	Particulate	Total	Vapor	Particulate	Total
			g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
83-32-9	Acenaphthene	Feed/PIC	5.66E-05	4.31E-10 (Note 5)	5.66E-05	5.66E-05	2.15E-15	5.66E-05
208-96-8	Acenaphthylene	Feed/PIC	1.69E-05 (Note 4)	4.31E-10 (Note 5)	1.69E-05	1.69E-05	2.15E-15	1.69E-05
75-07-0	Acetaldehyde	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
60-35-5	Acetamide	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
141-78-6	Ethyl acetate	Feed	6.31E-10	0.00E+00	6.31E-10	6.31E-10	0.00E+00	6.31E-10
108-05-4	vinyl acetate	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
75-05-8	Acetonitrile	Feed/PIC	1.46E-07	4.31E-10 (Note 5)	1.46E-07	1.46E-07	2.15E-15	1.46E-07
98-86-2	Acetophenone	Feed/PIC	3.73E-08	4.31E-10 (Note 5)	3.77E-08	3.73E-08	2.15E-15	3.73E-08
107-02-8	Acrolein	Feed	8.68E-09	0.00E+00	8.68E-09	8.68E-09	0.00E+00	8.68E-09
107-13-1	Acrylonitrile	Feed/PIC	5.91E-09	4.31E-10 (Note 5)	6.34E-09	5.91E-09	2.15E-15	5.91E-09
134-32-7	alpha-Naphthylamine	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
120-12-7	Anthracene	Feed/PIC	1.69E-05 (Note 4)	4.88E-12	1.69E-05	1.69E-05	2.44E-17	1.69E-05
71-43-2	Benzene	Feed/PIC	5.05E-10	4.31E-10 (Note 5)	9.36E-10	5.05E-10	2.15E-15	5.05E-10
50-32-8	Benzo(a)pyrene	Feed	6.77E-09	3.86E-11	6.81E-09	6.77E-09	1.93E-16	6.77E-09
191-24-2	Benzo(ghi)perylene	Feed/PIC	1.69E-05 (Note 4)	2.28E-09	1.69E-05	1.69E-05	1.14E-14	1.69E-05
117-81-7	Bis(2-ethylhexyl)phthalate	Feed/PIC	1.69E-05 (Note 4)	9.90E-10	1.69E-05	1.69E-05	4.95E-15	1.69E-05
75-27-4	Bromodichloromethane	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
74-83-9	Bromomethane	Feed/PIC	3.99E-10	4.31E-10 (Note 5)	8.30E-10	3.99E-10	2.15E-15	3.99E-10
123-72-8	Butanal	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
85-68-7	Butylbenzylphthalate	Feed/PIC	1.04E-04	1.33E-08	1.04E-04	1.04E-04	6.66E-14	1.04E-04
56-23-5	Carbon tetrachloride	Feed/PIC	3.05E-10	4.31E-10 (Note 5)	7.36E-10	3.05E-10	2.15E-15	3.05E-10
108-90-7	Chlorobenzene	Feed/PIC	1.93E-10	4.31E-10 (Note 5)	6.23E-10	1.93E-10	2.15E-15	1.93E-10
75-45-6	Chlorodifluoromethane	Feed	5.91E-10	0.00E+00	5.91E-10	5.91E-10	0.00E+00	5.91E-10
75-00-3	Chloroethane	Feed	3.99E-10	0.00E+00	3.99E-10	3.99E-10	0.00E+00	3.99E-10
67-66-3	Chloroform	Feed/PIC	2.00E-10	4.31E-10 (Note 5)	6.31E-10	2.00E-10	2.15E-15	2.00E-10
74-87-3	Chloromethane	Feed/PIC	7.95E-10	4.31E-10 (Note 5)	1.23E-09	7.95E-10	2.15E-15	7.95E-10
10061-01-5	cis-1,3-Dichloropropene	Feed	5.91E-10	0.00E+00	5.91E-10	5.91E-10	0.00E+00	5.91E-10
108-39-4	m-Cresol	Feed	4.29E-05	0.00E+00	4.29E-05	4.29E-05	0.00E+00	4.29E-05
95-48-7	2-Methylphenol	Feed	5.96E-05	0.00E+00	5.96E-05	5.96E-05	0.00E+00	5.96E-05
98-82-8	Isopropylbenzene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
110-82-7	Cyclohexane	Feed	5.91E-10	0.00E+00	5.91E-10	5.91E-10	0.00E+00	5.91E-10
108-94-1	Cyclohexanone	Feed	5.77E-07	0.00E+00	5.77E-07	5.77E-07	0.00E+00	5.77E-07
226-36-8	Dibenz[a,h]acridine	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
53-70-3	Dibenz[a,h]anthracene	Feed/PIC	1.45E-09	2.37E-09	3.82E-09	1.45E-09	1.18E-14	1.45E-09
224-42-0	Dibenz[a,j]acridine	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
191-30-0	Dibenzo(a,l)pyrene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
192-65-4	Dibenzo[a,e]pyrene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
189-64-0	Dibenzo[a,h]pyrene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
189-55-9	Dibenzo[a,i]pyrene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
75-71-8	Dichlorodifluoromethane	Feed	4.95E-10	0.00E+00	4.95E-10	4.95E-10	0.00E+00	4.95E-10
75-09-2	Methylenechloride	Feed/PIC	1.18E-07	4.31E-10 (Note 5)	1.19E-07	1.18E-07	2.15E-15	1.18E-07
84-66-2	Diethylphthalate	Feed/PIC	1.69E-05 (Note 4)	4.31E-10 (Note 5)	1.69E-05	1.69E-05	2.15E-15	1.69E-05
84-74-2	Di-n-butylphthalate	Feed/PIC	3.40E-04	4.79E-09	3.40E-04	3.40E-04	2.39E-14	3.40E-04
117-84-0	Di-n-octylphthalate	Feed	5.49E-05	2.22E-08	5.49E-05	5.49E-05	1.11E-13	5.49E-05
100-41-4	Ethylbenzene	Feed	3.34E-10	0.00E+00	3.34E-10	3.34E-10	0.00E+00	3.34E-10
60-29-7	Ethyl ether	Feed	2.22E-08	0.00E+00	2.22E-08	2.22E-08	0.00E+00	2.22E-08
106-93-4	Ethylene dibromide	Feed	1.60E-10	0.00E+00	1.60E-10	1.60E-10	0.00E+00	1.60E-10
75-21-8	Ethylene oxide (Oxirane)	Feed	3.44E-08	0.00E+00	3.44E-08	3.44E-08	0.00E+00	3.44E-08
206-44-0	Fluoranthene	Feed/PIC	5.57E-05	1.06E-09	5.57E-05	5.57E-05	5.32E-15	5.57E-05
86-73-7	Fluorene	Feed/PIC	1.69E-05 (Note 4)	4.31E-10 (Note 5)	1.69E-05	1.69E-05	2.15E-15	1.69E-05
75-02-5	Fluoroethene (vinyl fluoride)	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
50-00-0	Formaldehyde	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
87-68-3	Hexachlorobutadiene	Feed	1.01E-07	0.00E+00	1.01E-07	1.01E-07	0.00E+00	1.01E-07

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

CALC NO.: 24590-BOF-M4C-DEP-00001

SHEET REV: B

SHEET NO.: 112

BY: William Hix

DATE: 6/6/2016

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

CAS #	COPC	Feed or Feed/PIC (Note 1)	Unabated Streams			Abated Streams		
			DEP15			DEP18		
			DEP Vessel Vent			DEP Vessel Vent		
			Vapor	Particulate	Total	Vapor	Particulate	Total
			g/sec	g/sec	g/sec	g/sec	g/sec	g/sec
67-72-1	Hexachloroethane	Feed	2.36E-06	0.00E+00	2.36E-06	2.36E-06	0.00E+00	2.36E-06
628-73-9	Hexanenitrile	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
193-39-5	Indeno(1,2,3-cd)pyrene	Feed/PIC	1.69E-05 (Note 4)	2.43E-09	1.69E-05	1.69E-05	1.21E-14	1.69E-05
67-56-1	Methyl alcohol	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
1634-04-4	tert-Butyl methyl ether	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
122-39-4	Diphenyl amine	Feed	1.79E-08	0.00E+00	1.79E-08	1.79E-08	0.00E+00	1.79E-08
91-20-3	Naphthalene	Feed/PIC	5.29E-05 (Note 2)	4.31E-10 (Note 5)	5.29E-05	5.29E-05	2.15E-15	5.29E-05
109-74-0	Butanenitrile	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
71-36-3	1-Butanol	Feed	4.77E-07	0.00E+00	4.77E-07	4.77E-07	0.00E+00	4.77E-07
110-54-3	Hexane	Feed	3.12E-08	0.00E+00	3.12E-08	3.12E-08	0.00E+00	3.12E-08
98-95-3	Nitrobenzene	Feed/PIC	1.30E-07	4.31E-10 (Note 5)	1.31E-07	1.30E-07	2.15E-15	1.30E-07
621-64-7	N-Nitroso-di-n-propylamine	Feed	4.89E-07 (Note 2)	0.00E+00	4.89E-07	4.89E-07	0.00E+00	4.89E-07
10595-95-6	N-Nitrosomethylethylamine	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
59-89-2	Morpholine, 4-Nitroso-	Feed	1.21E-08 (Note 2)	0.00E+00	1.21E-08	1.21E-08	0.00E+00	1.21E-08
62-75-9	N-Nitrosodimethylamine	Feed	2.10E-09 (Note 2)	0.00E+00	2.10E-09	2.10E-09	0.00E+00	2.10E-09
87-86-5	Pentachlorophenol	Feed	9.76E-08	2.27E-13	9.76E-08	9.76E-08	1.14E-18	9.76E-08
110-59-8	Pentanenitrile	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
85-01-8	Phenanthrene	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
108-95-2	Phenol	Feed/PIC	1.34E-07	4.31E-10 (Note 5)	1.34E-07	1.34E-07	2.15E-15	1.34E-07
100-21-0	Phthalic acid	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
100-02-7	4-Nitrophenol	Feed/PIC	4.92E-05	1.17E-10	4.92E-05	4.92E-05	5.85E-16	4.92E-05
1336-36-3	Aroclors (Total PCB)	Feed	2.59E-05 (Note 2)	0.00E+00	2.59E-05	2.59E-05	0.00E+00	2.59E-05
107-12-0	Propionitrile	Feed	5.42E-08	0.00E+00	5.42E-08	5.42E-08	0.00E+00	5.42E-08
129-00-0	Pyrene	Feed/PIC	5.56E-05	7.95E-10	5.56E-05	5.56E-05	3.98E-15	5.56E-05
110-86-1	Pyridine	Feed	1.39E-07	0.00E+00	1.39E-07	1.39E-07	0.00E+00	1.39E-07
100-42-5	Styrene	Feed/PIC	1.60E-10	4.31E-10 (Note 5)	5.91E-10	1.60E-10	2.15E-15	1.60E-10
108-88-3	Toluene	Feed/PIC	8.34E-10	4.31E-10 (Note 5)	1.26E-09	8.34E-10	2.15E-15	8.34E-10
10061-02-6	trans-1,3-Dichloropropene	Feed	6.17E-10	0.00E+00	6.17E-10	6.17E-10	0.00E+00	6.17E-10
126-73-8	Tributyl phosphate	Feed	1.68E-05	1.57E-10	1.68E-05	1.68E-05	7.84E-16	1.68E-05
27154-33-2	Trichlorofluoroethane	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
75-69-4	Trichlorofluoromethane	Feed	4.86E-10	0.00E+00	4.86E-10	4.86E-10	0.00E+00	4.86E-10
75-50-3	Trimethylamine	Feed	1.69E-05 (Note 4)	0.00E+00	1.69E-05	1.69E-05	0.00E+00	1.69E-05
1330-20-7	Xylenes (total)	Feed/PIC	5.71E-08	4.31E-10 (Note 5)	5.75E-08	5.71E-08	2.15E-15	5.71E-08
75-15-0	Carbon Disulfide (Note 3)	Feed/PIC	2.92E-07	4.31E-10 (Note 5)	2.93E-07	2.92E-07	2.15E-15	2.92E-07
		TOTAL	2.33E-03	6.23E-08	2.33E-03	2.33E-03	3.12E-13	2.33E-03

Note 1: Particulate emissions of Organic COPCs that are present in both the feed and as a PIC will be reported with the Organic COPC results. If a Feed/PIC COPC has estimated particulate emissions using both the PIC emissions methodology and the feed organics methodology then the emissions estimate will be the sum of the results from the two methods.

Note 2: The unabated vapor emissions for these COPCs were evaluated using the Henry's Law method in Section 5.2.4.1

Note 3: Carbon disulfide emissions were calculated using the methodology for feed inorganic COPCs (Section 5.3.1) because the Tank Farm Feed ratio for carbon disulfide is provided in the units used for inorganic COPCs (g COPC / g Na). The results for carbon disulfide are listed with the feed organic COPCs because that is how it is classified per Ref. 9.1

Note 4: For feed organic COPCs without Tank Farms Average Ratios, the unabated vapor emissions rate represents the adjusted emissions rate assigned pre Assumption 6.2.28 based on the average non-zero unabated feed organic COPC vapor emissions rate.

Note 5: For Feed/PIC COPCs that are emitted as vapor phase type, the emissions reported as particulate represent the adjusted emissions rate assigned per Assumption 6.2.27 based on the average non-zero unabated PIC COPC particulate emissions rate.

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

BY: William Hix

CALC NO.: 24590-BOF-M4C-DEP-00001

DATE: 6/6/2016

SHEET REV: B

SHEET NO.: 113

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

Table 8-5 – PIC COPC Emissions from DVP System

CAS #	COPC	PIC or Feed/PIC	Unabated Streams	Abated Streams
			DEP15	DEP18
			DEP Vessel Vent	DEP Vessel Vent
			Particulate	Particulate
			g/sec	g/sec
100-25-4	1,4-Dinitrobenzene	PIC	2.44E-12	1.22E-17
100-44-7	Benzyl chloride	PIC	4.31E-10 (Note 2)	2.15E-15
100-47-0	Benzonitrile	PIC	4.31E-10 (Note 2)	2.15E-15
100-51-6	Benzyl alcohol	PIC	4.31E-10 (Note 2)	2.15E-15
100-52-7	Benzaldehyde	PIC	4.31E-10 (Note 2)	2.15E-15
101-77-9	4,4-Methylenedianiline	PIC	4.31E-10 (Note 2)	2.15E-15
103-33-3	Azobenzene	PIC	4.31E-10 (Note 2)	2.15E-15
103-65-1	n-Propyl benzene (Isocumene)	PIC	4.31E-10 (Note 2)	2.15E-15
104-51-8	n-Butylbenzene	PIC	4.31E-10 (Note 2)	2.15E-15
106-43-4	4-Chlorotoluene (p-Tolyl chloride)	PIC	4.31E-10 (Note 2)	2.15E-15
106-44-5	p-Cresol (4-methyl phenol)	PIC	4.31E-10 (Note 2)	2.15E-15
106-47-8	p-Chloroaniline	PIC	4.31E-10 (Note 2)	2.15E-15
106-49-0	p-Toluidine	PIC	4.31E-10 (Note 2)	2.15E-15
106-51-4	Quinone	PIC	4.31E-10 (Note 2)	2.15E-15
106-89-8	Epichlorohydrin (1-chloro-2,3 epoxypropane)	PIC	4.31E-10 (Note 2)	2.15E-15
107-19-7	Propargyl alcohol	PIC	4.31E-10 (Note 2)	2.15E-15
107-21-1	Ethylene glycol (1,2-ethanediol)	PIC	4.31E-10 (Note 2)	2.15E-15
107-98-2	Propylene glycol monomethyl ether	PIC	4.31E-10 (Note 2)	2.15E-15
108-60-1	bis (2-Chloroisopropyl)ether	PIC	4.31E-10 (Note 2)	2.15E-15
108-67-8	1,3,5-Trimethylbenzene	PIC	4.31E-10 (Note 2)	2.15E-15
108-86-1	Bromobenzene (Phenyl bromide)	PIC	4.31E-10 (Note 2)	2.15E-15
108-87-2	Methylcyclohexane	PIC	4.31E-10 (Note 2)	2.15E-15
109-75-1	3-Butenenitrile	PIC	4.31E-10 (Note 2)	2.15E-15
109-77-3	Malononitrile	PIC	4.31E-10 (Note 2)	2.15E-15
109-86-4	2-Methoxyethanol	PIC	4.31E-10 (Note 2)	2.15E-15
109-99-9	Tetrahydrofuran	PIC	4.31E-10 (Note 2)	2.15E-15
110-00-9	Furan	PIC	4.31E-10 (Note 2)	2.15E-15
110-83-8	Cyclohexene	PIC	4.31E-10 (Note 2)	2.15E-15
111-15-9	Ethylene glycol monoethyl ether acetate	PIC	4.31E-10 (Note 2)	2.15E-15
111-44-4	Bis(2-chloroethyl)ether	PIC	4.31E-10 (Note 2)	2.15E-15
111-65-9	n-Octane	PIC	4.31E-10 (Note 2)	2.15E-15
111-84-2	n-Nonane	PIC	4.31E-10 (Note 2)	2.15E-15
111-91-1	Bis(2-chloroethoxy)methane	PIC	7.32E-12	3.66E-17
1120-21-4	Undecane	PIC	4.31E-10 (Note 2)	2.15E-15
1120-71-4	1,3-Propane sultone	PIC	4.31E-10 (Note 2)	2.15E-15
112-30-1	1-Decanol	PIC	4.31E-10 (Note 2)	2.15E-15
112-31-2	Decanal	PIC	4.31E-10 (Note 2)	2.15E-15
112-40-3	Dodecane	PIC	4.31E-10 (Note 2)	2.15E-15
118-74-1	Hexachlorobenzene	PIC	4.31E-10 (Note 2)	2.15E-15
119-90-4	3,3'-Dimethoxybenzidine	PIC	3.41E-10	1.71E-15
122-66-7	1,2-Diphenylhydrazine	PIC	4.31E-10 (Note 2)	2.15E-15
123-33-1	Maleic hydrazide	PIC	4.31E-10 (Note 2)	2.15E-15
123-38-6	Propionaldehyde	PIC	4.31E-10 (Note 2)	2.15E-15
124-18-5	Decane	PIC	4.31E-10 (Note 2)	2.15E-15
124-48-1	Chlorodibromomethane	PIC	4.31E-10 (Note 2)	2.15E-15
131-11-3	Dimethyl Phthalate	PIC	4.31E-10 (Note 2)	2.15E-15
131-89-5	2-Cyclohexyl-4,6-dinitrophenol	PIC	1.52E-09	7.62E-15
132-64-9	Dibenzofuran	PIC	8.25E-13	4.13E-18
133-06-2	Captan	PIC	4.31E-10 (Note 2)	2.15E-15
135-98-8	sec-Butylbenzene	PIC	4.31E-10 (Note 2)	2.15E-15
145-73-3	Endothall	PIC	2.43E-09	1.21E-14
156-59-2	cis-1,2-Dichloroethene	PIC	4.31E-10 (Note 2)	2.15E-15
1746-01-6	2,3,7,8-Tetrachlorodibenzo(p)dioxin (TCDD)	PIC	5.65E-17	2.82E-22
192-97-2	Benzo(e)pyrene	PIC	2.61E-10	1.30E-15
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	PIC	4.44E-16	2.22E-21
205-82-3	Benzo[j]fluoranthene	PIC	1.00E-09	5.00E-15
205-99-2	Benzo(b)fluoranthene	PIC	8.29E-11	4.15E-16
207-08-9	Benzo(k)fluoranthene	PIC	1.80E-09	9.02E-15
218-01-9	Chrysene	PIC	6.78E-10	3.39E-15
2245-38-7	2,3,5-Trimethylnaphthalene	PIC	4.31E-10 (Note 2)	2.15E-15
23950-58-5	Pronamide	PIC	1.24E-10	6.22E-16
31508-00-6	2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	PIC	7.13E-14	3.56E-19
319-84-6	alpha-BHC	PIC	4.31E-10 (Note 2)	2.15E-15
319-85-7	beta-BHC	PIC	2.44E-12	1.22E-17

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

BY: William Hix
DATE: 6/6/2016

CALC NO.: 24590-BOF-M4C-DEP-00001

SHEET REV: B

SHEET NO.: 114

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

CAS #	COPC	PIC or Feed/PIC	Unabated Streams	Abated Streams
			DEP15	DEP18
			DEP Vessel Vent	DEP Vessel Vent
			Particulate	Particulate
			g/sec	g/sec
32598-13-3	3,3',4,4'-Tetrachlorobiphenyl (PCB 77)	PIC	5.98E-15	2.99E-20
32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	PIC	3.04E-15	1.52E-20
3268-87-9	Octachlorodibenzo(p)dioxin	PIC	8.00E-11	4.00E-16
32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	PIC	4.06E-17	2.03E-22
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	PIC	7.83E-12	3.91E-17
38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)	PIC	1.94E-15	9.68E-21
39001-02-0	Octachlorodibenzofuran	PIC	3.41E-11	1.70E-16
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	PIC	1.91E-16	9.55E-22
39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	PIC	5.96E-16	2.98E-21
40321-76-4	1,2,3,7,8-Pentachlorodibenzo(p)dioxin	PIC	1.25E-16	6.23E-22
4170-30-3	Crotonaldehyde (Propylene aldehyde)	PIC	4.31E-10 (Note 2)	2.15E-15
41851-50-7	Chlorocyclopentadiene	PIC	4.31E-10 (Note 2)	2.15E-15
460-19-5	Cyanogen (oxalonitrile)	PIC	4.31E-10 (Note 2)	2.15E-15
4786-20-3	2-Butenenitrile	PIC	4.31E-10 (Note 2)	2.15E-15
506-68-3	Cyanogen bromide (bromocyanide)	PIC	4.31E-10 (Note 2)	2.15E-15
506-77-4	Cyanogen chloride	PIC	4.31E-10 (Note 2)	2.15E-15
510-15-6	Chlorobenzilate	PIC	3.29E-10	1.65E-15
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran	PIC	2.67E-11	1.34E-16
51-28-5	2,4-Dinitrophenol	PIC	4.31E-10 (Note 2)	2.15E-15
51-79-6	Ethyl carbamate (urethane)	PIC	4.31E-10 (Note 2)	2.15E-15
52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	PIC	1.03E-15	5.13E-21
528-29-0	1,2-Dinitrobenzene (o-Dinitrobenzene)	PIC	2.44E-12	1.22E-17
532-27-4	2-Chloroacetophenone	PIC	4.31E-10 (Note 2)	2.15E-15
534-52-1	4,6-Dinitro-o-cresol	PIC	4.31E-10 (Note 2)	2.15E-15
5385-75-1	Dibenzo(a,e)fluoranthene	PIC	2.39E-09	1.20E-14
540-59-0	1,2-Dichloroethene (total) (1,2-Dichloroethylene)	PIC	4.31E-10 (Note 2)	2.15E-15
540-73-8	1,2-Dimethylhydrazine	PIC	4.31E-10 (Note 2)	2.15E-15
540-84-1	2,2,4-Trimethylpentane	PIC	4.31E-10 (Note 2)	2.15E-15
542-75-6	1,3-Dichloropropene	PIC	4.31E-10 (Note 2)	2.15E-15
542-88-1	Bis(chloromethyl)ether	PIC	4.31E-10 (Note 2)	2.15E-15
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran	PIC	1.53E-16	7.63E-22
56-55-3	Benzo(a)anthracene	PIC	1.29E-09	6.45E-15
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	PIC	2.44E-11	1.22E-16
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran	PIC	6.67E-11	3.33E-16
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran	PIC	1.02E-11	5.09E-17
57-24-9	Strychnine	PIC	2.42E-09	1.21E-14
57465-28-8	3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	PIC	1.35E-16	6.73E-22
57653-85-7	1,2,3,6,7,8,-Hexachlorodibenzo(p)dioxin	PIC	4.20E-16	2.10E-21
57-74-9	Chlordane	PIC	1.71E-11	8.54E-17
581-42-0	2,6-Dimethylnaphthalene	PIC	4.31E-10 (Note 2)	2.15E-15
584-84-9	2,4-Toluene diisocyanate	PIC	4.31E-10 (Note 2)	2.15E-15
58-89-9	gamma-BHC (Lindane)	PIC	4.31E-10 (Note 2)	2.15E-15
591-50-4	Benzene, iodo-	PIC	4.31E-10 (Note 2)	2.15E-15
593-60-2	Bromoethene (Vinyl bromide)	PIC	4.31E-10 (Note 2)	2.15E-15
60-11-7	Dimethyl aminoazobenzene	PIC	1.12E-09	5.61E-15
606-20-2	2,6-Dinitrotoluene	PIC	4.31E-10 (Note 2)	2.15E-15
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran	PIC	1.43E-16	7.14E-22
608-93-5	Pentachlorobenzene	PIC	4.31E-10 (Note 2)	2.15E-15
61626-71-9	Dichloropentadiene	PIC	4.31E-10 (Note 2)	2.15E-15
624-83-9	Methyl isocyanate	PIC	4.31E-10 (Note 2)	2.15E-15
62-50-0	Ethyl methanesulfonate	PIC	4.31E-10 (Note 2)	2.15E-15
62-53-3	Aniline	PIC	4.31E-10 (Note 2)	2.15E-15
64-18-6	Formic acid (methanoic acid)	PIC	4.31E-10 (Note 2)	2.15E-15
65510-44-3	2',3,4,4',5-Pentachlorobiphenyl (PCB 123)	PIC	9.52E-17	4.76E-22
65-85-0	Benzoic acid	PIC	4.31E-10 (Note 2)	2.15E-15
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran	PIC	2.12E-16	1.06E-21
69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)	PIC	6.16E-16	3.08E-21
70-30-4	Hexachlorophene	PIC	2.42E-09	1.21E-14
70362-50-4	3,4,4',5-Tetrachlorobiphenyl (PCB 81)	PIC	7.25E-17	3.62E-22
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	PIC	4.09E-11	2.04E-16
72-43-5	Methoxychlor	PIC	3.63E-10	1.82E-15
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran	PIC	3.48E-13	1.74E-18
74472-37-0	2,3,4,4',5-Pentachlorobiphenyl (PCB 114)	PIC	1.22E-16	6.12E-22
74-88-4	Iodomethane	PIC	4.31E-10 (Note 2)	2.15E-15
74-95-3	Methylene bromide	PIC	4.31E-10 (Note 2)	2.15E-15

CALCULATION SHEET

PROJECT: RPP-WTP

JOB NO.: 24590

BY: William Hix
DATE: 6/6/2016

CALC NO.: 24590-BOF-M4C-DEP-00001

SHEET REV: B

SHEET NO.: 115

SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

CAS #	COPC	PIC or Feed/PIC	Unabated Streams	Abated Streams
			DEP15	DEP18
			DEP Vessel Vent	DEP Vessel Vent
			Particulate	Particulate
			g/sec	g/sec
74-97-5	Bromochloromethane	PIC	4.31E-10 (Note 2)	2.15E-15
75-25-2	Bromoform	PIC	4.31E-10 (Note 2)	2.15E-15
75-29-6	2-Chloropropane	PIC	4.31E-10 (Note 2)	2.15E-15
75-44-5	Phosgene (hydrogen phosphide)	PIC	4.31E-10 (Note 2)	2.15E-15
76-01-7	Pentachloroethane	PIC	4.31E-10 (Note 2)	2.15E-15
764-41-0	1,4-Dichloro-2-butene	PIC	4.31E-10 (Note 2)	2.15E-15
76-44-8	Heptachlor	PIC	4.31E-10 (Note 2)	2.15E-15
765-34-4	Glycidylaldehyde	PIC	4.31E-10 (Note 2)	2.15E-15
77-47-4	Hexachlorocyclopentadiene	PIC	4.31E-10 (Note 2)	2.15E-15
77-78-1	Dimethyl sulfate	PIC	4.31E-10 (Note 2)	2.15E-15
80-62-6	Methyl methacrylate	PIC	4.31E-10 (Note 2)	2.15E-15
822-06-0	Hexamethylene-1,5-diisocyanate	PIC	4.31E-10 (Note 2)	2.15E-15
823-40-5	Toluene-2,6-diamine	PIC	4.31E-10 (Note 2)	2.15E-15
82-68-8	Pentachloronitrobenzene (PCNB)	PIC	4.31E-10 (Note 2)	2.15E-15
832-69-9	1-Methylphenanthrene	PIC	7.07E-11	3.54E-16
85-44-9	Phthalic anhydride (1,2-benzenedicarboxylic anhydride)	PIC	4.31E-10 (Note 2)	2.15E-15
87-61-6	1,2,3-Trichlorobenzene	PIC	4.31E-10 (Note 2)	2.15E-15
88-74-4	o-Nitroaniline (2-nitroaniline)	PIC	4.31E-10 (Note 2)	2.15E-15
90-04-0	o-Anisidine	PIC	4.31E-10 (Note 2)	2.15E-15
90-12-0	1-Methylnaphthalene	PIC	4.31E-10 (Note 2)	2.15E-15
91-22-5	Quinoline	PIC	4.31E-10 (Note 2)	2.15E-15
91-57-6	2-Methylnaphthalene	PIC	4.31E-10 (Note 2)	2.15E-15
91-94-1	3,3'-Dichlorobenzidine	PIC	1.26E-09	6.29E-15
924-16-3	N-Nitroso-di-n-Buethylamine	PIC	4.31E-10 (Note 2)	2.15E-15
94-59-7	Safrole (5-(2-Propenyl)-1,3-benzodioxole)	PIC	4.31E-10 (Note 2)	2.15E-15
94-75-7	2,4-D	PIC	1.24E-10	6.22E-16
95-49-8	o-Chlorotoluene	PIC	4.31E-10 (Note 2)	2.15E-15
95-53-4	o-Toluidine	PIC	4.31E-10 (Note 2)	2.15E-15
95-63-6	1,2,4-Trimethyl benzene	PIC	4.31E-10 (Note 2)	2.15E-15
95-94-3	1,2,4,5-Tetrachlorobenzene	PIC	4.31E-10 (Note 2)	2.15E-15
96-12-8	1,2-Dibromo-3-chloropropane	PIC	4.31E-10 (Note 2)	2.15E-15
96-18-4	1,2,3-Trichloropropane	PIC	4.31E-10 (Note 2)	2.15E-15
96-45-7	Ethylene thiourea	PIC	4.31E-10 (Note 2)	2.15E-15
97-63-2	Ethyl methacrylate	PIC	4.31E-10 (Note 2)	2.15E-15
98-01-1	Furfural	PIC	4.31E-10 (Note 2)	2.15E-15
98-06-6	tert-Butyl benzene	PIC	4.31E-10 (Note 2)	2.15E-15
98-07-7	Benzotrichloride	PIC	4.31E-10 (Note 2)	2.15E-15
98-83-9	Methyl styrene (mixed isomers)	PIC	4.31E-10 (Note 2)	2.15E-15
99-35-4	1,3,5-Trinitrobenzene	PIC	1.95E-11	9.76E-17
99-65-0	1,3-Dinitrobenzene	PIC	4.31E-10 (Note 2)	2.15E-15
99-87-6	p-Cymene	PIC	4.31E-10 (Note 2)	2.15E-15
105-67-9	2,4-Dimethylphenol	PIC	4.31E-10 (Note 2)	2.15E-15
		Total	6.99E-08	3.50E-13
100-02-7	p-Nitrophenol	Feed/PIC	Note 1	
100-42-5	Styrene	Feed/PIC		
106-46-7	1,4-Dichlorobenzene	Feed/PIC		
107-06-2	1,2-Dichloroethane	Feed/PIC		
107-13-1	Acrylonitrile	Feed/PIC		
108-88-3	Toluene	Feed/PIC		
108-90-7	Chlorobenzene	Feed/PIC		
108-95-2	Phenol	Feed/PIC		
117-81-7	bis(2-Ethylhexyl)phthalate	Feed/PIC		
120-12-7	Anthracene	Feed/PIC		
121-14-2	2,4-Dinitrotoluene	Feed/PIC		
129-00-0	Pyrene	Feed/PIC		
1330-20-7	Xylenes (total)	Feed/PIC		
191-24-2	Benzo(g,h,i)perylene	Feed/PIC		
193-39-5	Indeno(1,2,3-cd)pyrene	Feed/PIC		
206-44-0	Fluoranthene	Feed/PIC		
208-96-8	Acenaphthylene	Feed/PIC		
53-70-3	Dibenz[a,h]anthracene	Feed/PIC		
56-23-5	Carbon tetrachloride	Feed/PIC		
67-64-1	2-Propanone (Acetone)	Feed/PIC		
67-66-3	Chloroform	Feed/PIC		
71-43-2	Benzene	Feed/PIC		
74-83-9	Bromomethane	Feed/PIC		
74-87-3	Chloromethane	Feed/PIC		

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CAS #	COPC	PIC or Feed/PIC	Unabated Streams	Abated Streams
			DEP15	DEP18
			DEP Vessel Vent	DEP Vessel Vent
			Particulate	Particulate
			g/sec	g/sec
75-05-8	Acetonitrile	Feed/PIC		
75-09-2	Dichloromethane (Methylene Chloride)	Feed/PIC		
75-15-0	Carbon disulfide	Feed/PIC		
78-93-3	2-Butanone	Feed/PIC		
79-01-6	1,1,2-Trichloroethylene	Feed/PIC		
83-32-9	Acenaphthene	Feed/PIC		
84-66-2	Diethyl phthalate	Feed/PIC		
84-74-2	Di-n-butylphthalate	Feed/PIC		
85-68-7	Butylbenzylphthalate	Feed/PIC		
86-73-7	Fluorene	Feed/PIC		
88-75-5	2-Nitrophenol	Feed/PIC		
91-20-3	Naphthalene	Feed/PIC		
98-86-2	Acetophenone	Feed/PIC		
98-95-3	Nitrobenzene	Feed/PIC		

Note 1: Particulate emissions of Organic COPCs that are present in both the feed and as a PIC will be reported with the Organic COPC results. If a Feed/PIC COPC has estimated particulate emissions using both the PIC emissions methodology and the feed organics methodology then the emissions estimate will be the sum of the results from the two methods.

Note 2: For PIC COPCs that are emitted as vapor phase type, the emissions reported as particulate represent the adjusted emissions rate assigned per Assumption 6.2.27 based on the average non-zero unabated PIC COPC particulate emissions rate.

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Table 8-6 – Inorganic COPC Emissions from DVP System

CAS #	COPC	Unabated Streams	Abated Streams
		DEP15	DEP18
		DEP Vessel Vent	DEP Vessel Vent
		g/sec	g/sec
7440-22-4	Ag	1.92E-07	9.59E-13
7429-90-5	Al	2.12E-04	1.06E-09
7440-38-2	As	2.64E-07	1.32E-12
7440-39-3	Ba	4.56E-07	2.28E-12
7440-41-7	Be	2.39E-08	1.20E-13
24959-67-9	Br	5.36E-07	2.68E-12
7440-43-9	Cd	4.06E-07	2.03E-12
16887-00-6	Cl	2.02E-05	1.01E-10
57-12-5	CN ^(c)	1.26E-04	1.26E-04
7440-48-4	Co	8.02E-08	4.01E-13
7440-47-3	Cr	1.44E-05	7.20E-11
7440-50-8	Cu	1.46E-07	7.28E-13
16984-48-8	F	3.14E-05	1.57E-10
7439-89-6	Fe	3.09E-05	1.54E-10
7439-97-6	Hg	1.48E-07	7.38E-13
7439-93-2	Li	1.00E-07	5.01E-13
7439-95-4	Mg	1.13E-06	5.67E-12
7439-96-5	Mn	4.02E-06	2.01E-11
7439-98-7	Mo	3.35E-07	1.68E-12
7440-23-5	Na	1.21E-03	6.04E-09
7664-41-7	NH3 ^(c)	1.01E-01	1.01E-01
7440-02-0	Ni	2.41E-06	1.20E-11
14797-65-0	NO2	2.90E-04	1.45E-09
14797-55-8	NO3	1.36E-03	6.81E-09
7723-14-0	P	0.00E+00	0.00E+00
7439-92-1	Pb	2.01E-06	1.01E-11
14265-44-2	PO4	1.26E-04	6.29E-10
7440-16-6	Rh	3.02E-07	1.51E-12
7704-34-9	S	0.00E+00	0.00E+00
7440-36-0	Sb	2.08E-07	1.04E-12
7782-49-2	Se	2.94E-07	1.47E-12
7440-31-5	Sn	2.83E-07	1.41E-12
14808-79-8	SO4	9.39E-05	4.69E-10
7440-24-6	Sr	1.03E-06	5.16E-12
7440-25-7	Ta	9.83E-08	4.92E-13
7440-28-0	Tl	7.63E-07	3.81E-12
7440-61-1	UTOTAL	1.57E-05	7.87E-11
7440-62-2	V	1.33E-07	6.63E-13
7440-33-7	W	2.06E-06	1.03E-11
7440-65-5	Y	8.18E-08	4.09E-13
7440-66-6	Zn	2.87E-07	1.43E-12
7440-67-7	Zr	9.97E-06	4.98E-11
593-74-8	Dimethyl Mercury ^(c)	5.29E-07	5.29E-07
10102-44-0	Nitrogen dioxide ^(a)	0.00E+00	0.00E+00
124-38-9	Carbon dioxide ^(a)	0.00E+00	0.00E+00
630-08-0	Carbon monoxide ^(a)	0.00E+00	0.00E+00
10028-15-6	Ozone ^(a)	0.00E+00	0.00E+00
7446-09-5	Sulfur dioxide ^(a)	0.00E+00	0.00E+00
7647-01-0	Hydrogen chloride ^(a)	0.00E+00	0.00E+00
7664-39-3	Hydrogen Fluoride ^(a)	0.00E+00	0.00E+00
7782-41-4	Fluorine gas ^(a)	0.00E+00	0.00E+00
7782-50-5	Chlorine ^(a)	0.00E+00	0.00E+00
22967-92-6	Methyl mercury ^(b)	0.00E+00	0.00E+00
TOTAL		1.04E-01	1.01E-01

(a) Emissions of these stack inorganic COPCs are zero (Assumption 6.1.31).

(b) Methyl mercury emissions are grouped with total mercury emissions (Assumption 6.2.25)

(c) COPCs emitted in vapor phase

Table 8-7 – Total Particulate Emissions from DVP System

	Unabated Streams	Abated Streams
	DEP15	DEP18
	DEP Vessel Vent	DEP Vessel Vent
		g/sec
Feed Inorganic Particulate	3.43E-03	1.72E-08
Radionuclide Particulate	1.72E-05	8.60E-11
Feed Organic Particulate	6.23E-08	3.12E-13
PIC Particulate	6.99E-08	3.50E-13
TOTAL Particulate	3.45E-03	1.73E-08

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Table 8-8 – Summary of COPC Unabated Emissions Exceeding De Minimis Values

CAS #	COPC	De minimis emissions limit for COPC <i>i</i> , standardized to lb/yr	Feed Organic COPCs - Total Unabated Emissions of COPC <i>i</i> , in lb/yr	Difference: Feed Organic COPC minus de minimis, in lb/yr
91-20-3	Naphthalene	2.82E-01	3.68E+00	3.40E+00
621-64-7	n-Nitrosodi-n-propylamine	4.80E-03	3.40E-02	2.92E-02
1336-36-3	Polychlorinated Biphenyls, NOS	1.68E-02	1.80E+00	1.79E+00
56-49-5	3-Methylcholanthrene	1.53E-03	1.17E+00	1.17E+00
3697-24-3	5-Methylchrysene	8.72E-03	1.17E+00	1.16E+00
602-87-9	5-Nitroacenaphthene	2.59E-01	1.17E+00	9.14E-01
60-35-5	Acetamide	4.80E-01	1.17E+00	6.93E-01
75-27-4	Bromodichloromethane	2.59E-01	1.17E+00	9.14E-01
72-55-9	DDE	9.88E-02	1.17E+00	1.07E+00
117-81-7	Di(2-ethylhexyl)phthalate	4.00E-01	1.17E+00	7.73E-01
226-36-8	Dibenz[a,h]acridine	8.72E-02	1.17E+00	1.09E+00
224-42-0	Dibenz[a,j]acridine	8.72E-02	1.17E+00	1.09E+00
192-65-4	Dibenzo[a,e]pyrene	8.72E-03	1.17E+00	1.16E+00
189-64-0	Dibenzo[a,h]pyrene	8.72E-04	1.17E+00	1.17E+00
189-55-9	Dibenzo[a,i]pyrene	8.72E-04	1.17E+00	1.17E+00
191-30-0	Dibenzo[a,l]pyrene	8.72E-04	1.17E+00	1.17E+00
193-39-5	Indeno[1,2,3-cd]pyrene	8.72E-02	1.17E+00	1.09E+00
10595-95-6	n-Nitroso-n-methylethylamine	1.53E-03	1.17E+00	1.17E+00
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	5.05E-07	1.70E-06	1.19E-06
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	2.52E-06	2.84E-06	3.21E-07
7664-41-7	Ammonia	1.70E+02	7.00E+03	6.83E+03
7440-43-9	Cadmium & Compounds	2.28E-03	2.82E-02	2.59E-02
18540-29-9	Chromium (VI)	6.40E-05	1.00E+00	1.00E+00
593-74-8	Dimethyl mercury	3.65E-97	3.67E-02	3.67E-02

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9 Tracked References

- 9.1 24590-WTP-RPT-ENV-10-001, Rev. 0 – *Constituents of Potential Concern for the WTP Air and Dangerous Waste Permits*
- 9.2 24590-WTP-RPT-ENV-16-001, Rev. 0 – *Feed Vector Development in Support of WTP Environmental Risk Assessment Activities*
- 9.3 24590-WTP-ICD-MG-01-030, Rev. 0 - *ICD 30 – Interface Control Document for Direct LAW Feed*
- 9.4 CCN 129507, Rev. N/A - *Update 2: Vapor Phase Partitioning Coefficients*
- 9.5 24590-BOF-M5-V17T-00011, Rev. 0 - *Process Flow Diagram Direct Feed Effluent Transfer (System DEP)*
- 9.6 24590-BOF-M5-V17T-00012, Rev. 0 - *Process Flow Diagram Direct Feed Effluent Evaporator (System DEP)*
- 9.7 24590-BOF-M5-V17T-00013, Rev. 0 - *Process Flow Diagram Direct Feed Concentrate Transfer (System DEP)*
- 9.8 24590-BOF-M5-V17T-00014, Rev. 0 - *Process Flow Diagram Direct Feed Process Condensate Transfer (System DEP)*
- 9.9 24590-WTP-RPT-ENV-01-004, Rev. 1 – *Best Available Radionuclide Control Technology Analysis for the WTP*
- 9.10 24590-BOF-MVC-DEP-00009, Rev. B - *Batch Sizing Calculation of DEP (Direct Feed LAW Effluent Management Facility Process System) Vessels: DEP-VSL-00001, -00002, -00003A/B/C, -00004A/B, -00005A/B*
- 9.11 24590-BOF-M6C-DVP-00001, Rev. A - *DFLAW EMF Vessel Vent Process System (DVP) Line Sizing*
- 9.12 24590-WTP-RPT-ENV-01-008, Rev. 4 - *Radioactive Air Emissions Notice of Construction Permit Application for the Hanford Tank Waste Treatment and Immobilization Plant*
- 9.13 24590-WTP-HAC-50-00005, Rev. D - *Calculations for Annual Possession Quantity, Emission Rates, and Dose Rate Estimates for Pretreatment, LAW Vitrification, and HLW Vitrification Plants Supporting Air Permitting Activities*
- 9.14 24590-WTP-RPT-PO-03-008, Rev. 2 – *Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant*
- 9.15 24590-WTP-RPT-PE-11-010, Rev. 0 – *WTP Feed and Organic Generation Rates and Decontamination Factors for 2011-2012 Emissions Report*

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- 9.16 24590-PTF-3YD-CNP-00001, Rev. 2 – *System Description for the Cesium Nitric Acid Recovery Process – System CNP*
- 9.17 24590-BOF-MEC-DEP-00001, Rev. A - *DFLAW EMF Process System (DEP) Evaporator Operating Conditions, Heating/Cooling Duty, and Utility Requirements*
- 9.18 24590-WTP-M3C-50-00001, Rev. 1 – *Physical Properties Equations for Liquid Water*
- 9.19 24590-WTP-M4C-V37T-00011, Rev. 0, *FEP and TLP Evaporator and Condensers Decontamination Factor Calculation*
- 9.20 24590-LAW-MVC-RLD-00007, Rev. 0 - *Process Data Input for LAW SBS Condensate Collection Vessel, RLD-VSL-00005 and Discharge Pumps (RLD-PMP-00003A/B)*
- 9.21 24590-LAW-MVC-RLD-00009, Rev. 0 - *Process Data Input for LAW C3/C5 Drains/Sump Collection Vessel (RLD-VSL-00004) and Transfer Pumps (RLD-PMP-00002A/B) as modified by the following ECCNs:*
 - (1) 24590-LAW-MVE-RLD-00001 - *Change to Safety Factor Value for the High Humidity Case Listed in Calculation 24590-LAW-MVC-RLD-00009*
 - (2) 24590-LAW-MVE-RLD-00002 - *Provide Adequate and Proper Verification on document 24590-LAW-MVC-RLD-00009*
- 9.22 24590-WTP-DB-PET-09-001, Rev. 1 - *Process Inputs Basis of Design (PIBOD)*
- 9.23 24590-WTP-M4C-V11T-00012, Rev. 2 – *Calculation of Process Stream Properties for the WTP*
- 9.24 CCN 160522, Rev. N/A - *SRNL Letter "Input for Dimethylmercury Formation and Partitioning"*
- 9.25 24590-WTP-M4C-V11T-00013, Rev. A – *Estimated Concentrations of Dimethylmercury in WTP Process Streams*
- 9.26 24590-LAW-MVC-LVP-00001, Rev. 2, *Sizing Calculation for Caustic Collection Tank LVP-TK-00001*
- 9.27 24590-BOF-MVC-DEP-00011, Rev. B - *Process Data for the Low Point Drain Vessel, DEP-VSL-00001, and Pumps, DEP-PMP-00001A/B*
- 9.28 24590-PTF-MEC-CNP-00004, Rev. B – *Loop Volume Calculation for CNP Evaporator Recirculation Loop*
- 9.29 24590-WTP-RPT-PR-01-011, Rev. 0 – *Mercury Pathway and Treatment Assessment for the WTP*
- 9.30 24590-WTP-CSER-ENS-08-0001, Rev. 0b – *Preliminary Criticality Safety Evaluation Report for the WTP*
- 9.31 24590-BOF-MVC-DEP-00003, Rev. A - *Process Data for the Evaporator Feed Vessel (DEP-VSL-00002), Transfer Pumps (DEP-PMP-00002A/B), and Recirculation Pumps (DEP-PMP-00012A/B/C)*
- 9.32 24590-BOF-MVC-DEP-00010, Rev. A - *Process Data for the Evaporator Concentrate Vessels, DEP-VSL-00003A/B/C, and Pumps, DEP-PMP-00003A/B*

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- 9.33 24590-BOF-MVC-DEP-00007, Rev. A - *Process Data for the Overhead Sampling Vessels (DEP-VSL-00004A/B) and Pumps (DEP-PMP-00004A/B/C)*
- 9.34 24590-BOF-MVC-DEP-00008, Rev. A - *Process Data for the Process Condensate Lag Storage Vessels (DEP-VSL-00005A/B), Transfer Pumps (DEP-PMP-00005A/B), and Recirculation Pumps (DEP-PMP-00015A/B/C)*
- 9.35 24590-PTF-3YD-TLP-00001, Rev. 2 – *System Description for the Treated LAW Evaporation Process (TLP)*
- 9.36 24590-BOF-M8-C3V-00002001, Rev. A – *BOF/EMF Utility/Process Bldgs – Plant Room V&ID ACV Exhaust System*
- 9.37 24590-CM-HC4-W000-00193-01-00001, Rev. A, *Report - Aerosol Production in WTP Process Vessels - A Review of Recent Aerosol Testing*

10 References

- 10.1 *Risk Assessment Information System*. Oak Ridge National Laboratory. http://rais.ornl.gov/cgi-bin/tools/TOX_search?select=rad_spef (Accessed 05/27/2016, see Attachment B).
- 10.2 DOE-HDBK-3010-94 - *DOE Handbook Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities Volume I - Analysis of Experimental Data*. Department of Energy. December 1994, Reaffirmed 2013.
- 10.3 Lindeburg, Michael R. 2013. *Chemical Engineering Reference Manual for the PE Exam*. Seventh Edition. Professional Publications, Inc., Belmont, CA.
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- 10.7 Washington Administrative Code (WAC) 173-460-150 - *Table of ASIL, SQER and de minimis emission values*.
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- 10.9 Sander, Rolf. 1999. *Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry*. Max-Planck Institute of Chemistry. Mainz, Germany. <http://www.henrys-law.org/henry-3.0.pdf> (Accessed 05/27/2016)
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SUBJECT: DFLAW Effluent Management Facility Air Emissions Estimate

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11 Attachments

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Attachment A - WTP COPCs Complete List

The following tables list the chemicals and radionuclides considered COPCs for WTP per Ref. 9.1 Table 2-1.

Table A-1 – WTP Radionuclide COPCs

CAS #	COPC
13967-48-1	106Ru
378253-44-2	113mCd
14234-35-6	125Sb
15832-50-5	126Sn
15046-84-1	129I
13967-70-9	134Cs
10045-97-3	137Cs
378253-40-8	137mBa
14762-75-5	14C
15715-94-3	151Sm
14683-23-9	152Eu
15585-10-1	154Eu
14391-16-3	155Eu
13982-63-3	226Ra
14952-40-0	227Ac
15262-20-1	228Ra
15594-54-4	229Th
14331-85-2	231Pa
7440-29-1	232Th
14158-29-3	232U
13968-55-3	233U
13966-29-5	234U
15117-96-1	235U
13982-70-2	236U
13994-20-2	237Np
13981-16-3	238Pu
7440-61-1R	238U
15117-48-3	239Pu
14119-33-6	240Pu
14596-10-2	241Am
14119-32-5	241Pu
15510-73-3	242Cm
13982-10-0	242Pu
14993-75-0	243Am
15757-87-6	243Cm
13981-15-2	244Cm
10028-17-8	3H
14336-70-0	59Ni
10198-40-0	60Co
13981-37-8	63Ni
15758-45-9	79Se
10098-97-2	90Sr
10098-91-6	90Y
378782-82-2	93mNb
15751-77-6	93Zr
14133-76-7	99Tc

Table A-2 – WTP Organic COPCs

CAS #	COPC	Feed Organic	PIC	Feed/PIC ^(a)
630-20-6	1,1,1,2-Tetrachloroethane	X		
71-55-6	1,1,1-Trichloroethane	X		
79-34-5	1,1,2,2-Tetrachloroethane	X		
127-18-4	Tetrachloroethene	X		
79-00-5	1,1,2-Trichloroethane	X		
79-01-6	Trichloroethene			X
92-52-4	Biphenyl	X		
75-34-3	1,1-Dichloroethane	X		
75-35-4	1,1-Dichloroethene	X		
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	X		
120-82-1	1,2,4-Trichlorobenzene	X		
95-50-1	1,2-Dichlorobenzene	X		
107-06-2	1,2-Dichloroethane			X
78-87-5	1,2-Dichloropropane	X		
106-88-7	1,2-Epoxybutane	X		
156-60-5	1,2-trans-Dichloroethene	X		
106-99-0	1,3-Butadiene	X		
541-73-1	1,3-Dichlorobenzene	X		
106-46-7	1,4-Dichlorobenzene			X
123-91-1	1,4-Dioxane	X		
75-01-4	Vinyl chloride	X		
58-90-2	2,3,4,6-Tetrachlorophenol	X		
95-95-4	2,4,5-Trichlorophenol	X		
88-06-2	2,4,6-Trichlorophenol	X		
120-83-2	2,4-Dichlorophenol	X		
121-14-2	2,4-Dinitrotoluene			X
128-37-0	2,6-Bis(1,1-dimethylethyl)-4-methylphenol	X		
78-93-3	2-Butanone			X
111-76-2	2-Butoxyethanol	X		
91-58-7	2-Chloronaphthalene	X		
95-57-8	2-Chlorophenol	X		
110-80-5	2-Ethoxyethanol	X		
104-76-7	2-Ethyl-1-hexanol	X		
591-78-6	2-Hexanone	X		
126-98-7	2-Methyl-2-propenenitrile	X		
78-83-1	Isobutanol	X		
88-75-5	2-Nitrophenol			X
79-46-9	2-Nitropropane	X		
67-64-1	Acetone			X
79-10-7	2-Propenoic acid	X		
67-63-0	Isopropyl alcohol	X		
107-05-1	3-Chloropropene	X		
589-38-8	3-Hexanone	X		
56-49-5	3-Methylcholanthrene	X		
72-55-9	4,4-DDE	X		
101-55-3	4-Bromophenylphenyl ether	X		
59-50-7	4-Chloro-3-methylphenol	X		
100-40-3	4-Ethenylcyclohexene	X		
108-10-1	Hexone	X		
3697-24-3	5-Methylchrysene	X		
602-87-9	5-Nitroacenaphthene	X		
83-32-9	Acenaphthene			X
208-96-8	Acenaphthylene			X

CAS #	COPC	Feed Organic	PIC	Feed/PIC ^(a)
75-07-0	Acetaldehyde	X		
60-35-5	Acetamide	X		
141-78-6	Ethyl acetate	X		
108-05-4	vinyl acetate	X		
75-05-8	Acetonitrile			X
98-86-2	Acetophenone			X
107-02-8	Acrolein	X		
107-13-1	Acrylonitrile			X
134-32-7	alpha-Naphthylamine	X		
120-12-7	Anthracene			X
71-43-2	Benzene			X
50-32-8	Benzo(a)pyrene	X		
191-24-2	Benzo(ghi)perylene			X
117-81-7	Bis(2-ethylhexyl)phthalate			X
75-27-4	Bromodichloromethane	X		
74-83-9	Bromomethane			X
123-72-8	Butanal	X		
85-68-7	Butylbenzylphthalate			X
56-23-5	Carbon tetrachloride			X
108-90-7	Chlorobenzene			X
75-45-6	Chlorodifluoromethane	X		
75-00-3	Chloroethane	X		
67-66-3	Chloroform			X
74-87-3	Chloromethane			X
10061-01-5	cis-1,3-Dichloropropene	X		
108-39-4	m-Cresol	X		
95-48-7	2-Methylphenol	X		
98-82-8	Isopropylbenzene	X		
110-82-7	Cyclohexane	X		
108-94-1	Cyclohexanone	X		
226-36-8	Dibenz[a,h]acridine	X		
53-70-3	Dibenz[a,h]anthracene			X
224-42-0	Dibenz[a,j]acridine	X		
191-30-0	Dibenzo(a,l)pyrene	X		
192-65-4	Dibenzo[a,e]pyrene	X		
189-64-0	Dibenzo[a,h]pyrene	X		
189-55-9	Dibenzo[a,i]pyrene	X		
75-71-8	Dichlorodifluoromethane	X		
75-09-2	Methylenechloride			X
84-66-2	Diethylphthalate			X
84-74-2	Di-n-butylphthalate			X
117-84-0	Di-n-octylphthalate	X		
100-41-4	Ethylbenzene	X		
60-29-7	Ethyl ether	X		
106-93-4	Ethylene dibromide	X		
75-21-8	Ethylene oxide (Oxirane)	X		
206-44-0	Fluoranthene			X
86-73-7	Fluorene			X
75-02-5	Fluoroethene (vinyl fluoride)	X		
50-00-0	Formaldehyde	X		
87-68-3	Hexachlorobutadiene	X		
67-72-1	Hexachloroethane	X		
628-73-9	Hexanenitrile	X		
193-39-5	Indeno(1,2,3-cd)pyrene			X

CAS #	COPC	Feed Organic	PIC	Feed/PIC ^(a)
67-56-1	Methyl alcohol	X		
1634-04-4	tert-Butyl methyl ether	X		
122-39-4	Diphenyl amine	X		
91-20-3	Naphthalene			X
109-74-0	Butanenitrile	X		
71-36-3	1-Butanol	X		
110-54-3	Hexane	X		
98-95-3	Nitrobenzene			X
621-64-7	N-Nitroso-di-n-propylamine	X		
10595-95-6	N-Nitrosomethylethylamine	X		
59-89-2	Morpholine, 4-Nitroso-	X		
62-75-9	N-Nitrosodimethylamine	X		
87-86-5	Pentachlorophenol	X		
110-59-8	Pentanenitrile	X		
85-01-8	Phenanthrene	X		
108-95-2	Phenol			X
100-21-0	Phthalic acid	X		
100-02-7	4-Nitrophenol			X
1336-36-3	Aroclors (Total PCB)	X		
107-12-0	Propionitrile	X		
129-00-0	Pyrene			X
110-86-1	Pyridine	X		
100-42-5	Styrene			X
108-88-3	Toluene			X
10061-02-6	trans-1,3-Dichloropropene	X		
126-73-8	Tributyl phosphate	X		
27154-33-2	Trichlorofluoroethane	X		
75-69-4	Trichlorofluoromethane	X		
75-50-3	Trimethylamine	X		
1330-20-7	Xylenes (total)			X
75-15-0	Carbon disulfide			X
100-25-4	1,4-Dinitrobenzene		X	
100-44-7	Benzyl chloride		X	
100-47-0	Benzonitrile		X	
100-51-6	Benzyl alcohol		X	
100-52-7	Benzaldehyde		X	
101-77-9	4,4-Methylenedianiline		X	
103-33-3	Azobenzene		X	
103-65-1	n-Propyl benzene (Isocumene)		X	
104-51-8	n-Butylbenzene		X	
106-43-4	4-Chlorotoluene (p-Tolyl chloride)		X	
106-44-5	p-Cresol (4-methyl phenol)		X	
106-47-8	p-Chloroaniline		X	
106-49-0	p-Toluidine		X	
106-51-4	Quinone		X	
106-89-8	Epichlorohydrin (1-chloro-2,3 epoxypropane)		X	
107-19-7	Propargyl alcohol		X	
107-21-1	Ethylene glycol (1,2-ethanediol)		X	
107-98-2	Propylene glycol monomethyl ether		X	
108-60-1	bis (2-Chloroisopropyl)ether		X	
108-67-8	1,3,5-Trimethylbenzene		X	
108-86-1	Bromobenzene (Phenyl bromide)		X	
108-87-2	Methylcyclohexane		X	
109-75-1	3-Butenenitrile		X	

CAS #	COPC	Feed Organic	PIC	Feed/PIC ^(a)
109-77-3	Malononitrile		X	
109-86-4	2-Methoxyethanol		X	
109-99-9	Tetrahydrofuran		X	
110-00-9	Furan		X	
110-83-8	Cyclohexene		X	
111-15-9	Ethylene glycol monoethyl ether acetate		X	
111-44-4	Bis(2-chloroethyl)ether		X	
111-65-9	n-Octane		X	
111-84-2	n-Nonane		X	
111-91-1	Bis(2-chloroethoxy)methane		X	
1120-21-4	Undecane		X	
1120-71-4	1,3-Propane sultone		X	
112-30-1	1-Decanol		X	
112-31-2	Decanal		X	
112-40-3	Dodecane		X	
118-74-1	Hexachlorobenzene		X	
119-90-4	3,3'-Dimethoxybenzidine		X	
122-66-7	1,2-Diphenylhydrazine		X	
123-33-1	Maleic hydrazide		X	
123-38-6	Propionaldehyde		X	
124-18-5	Decane		X	
124-48-1	Chlorodibromomethane		X	
131-11-3	Dimethyl Phthalate		X	
131-89-5	2-Cyclohexyl-4,6-dinitrophenol		X	
132-64-9	Dibenzofuran		X	
133-06-2	Captan		X	
135-98-8	sec-Butylbenzene		X	
145-73-3	Endothall		X	
156-59-2	cis-1,2-Dichloroethene		X	
1746-01-6	2,3,7,8-Tetrachlorodibenzo(p)dioxin (TCDD)		X	
192-97-2	Benzo(e)pyrene		X	
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin		X	
205-82-3	Benzo[j]fluoranthene		X	
205-99-2	Benzo(b)fluoranthene		X	
207-08-9	Benzo(k)fluoranthene		X	
218-01-9	Chrysene		X	
2245-38-7	2,3,5-Trimethylnaphthalene		X	
23950-58-5	Pronamide		X	
31508-00-6	2,3',4,4',5-Pentachlorobiphenyl (PCB 118)		X	
319-84-6	alpha-BHC		X	
319-85-7	beta-BHC		X	
32598-13-3	3,3',4,4'-Tetrachlorobiphenyl (PCB 77)		X	
32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)		X	
3268-87-9	Octachlorodibenzo(p)dioxin		X	
32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)		X	
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin		X	
38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)		X	
39001-02-0	Octachlorodibenzofuran		X	
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin		X	
39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)		X	
40321-76-4	1,2,3,7,8-Pentachlorodibenzo(p)dioxin		X	
4170-30-3	Crotonaldehyde (Propylene aldehyde)		X	
41851-50-7	Chlorocyclopentadiene		X	
460-19-5	Cyanogen (oxalonitrile)		X	

CAS #	COPC	Feed Organic	PIC	Feed/PIC ^(a)
4786-20-3	2-Butenenitrile		X	
506-68-3	Cyanogen bromide (bromocyanide)		X	
506-77-4	Cyanogen chloride		X	
510-15-6	Chlorobenzilate		X	
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran		X	
51-28-5	2,4-Dinitrophenol		X	
51-79-6	Ethyl carbamate (urethane)		X	
52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)		X	
528-29-0	1,2-Dinitrobenzene (o-Dinitrobenzene)		X	
532-27-4	2-Chloroacetophenone		X	
534-52-1	4,6-Dinitro-o-cresol		X	
5385-75-1	Dibenzo(a,e)fluoranthene		X	
540-59-0	1,2-Dichloroethene (total) (1,2-Dichloroethylene)		X	
540-73-8	1,2-Dimethylhydrazine		X	
540-84-1	2,2,4-Trimethylpentane		X	
542-75-6	1,3-Dichloropropene		X	
542-88-1	Bis(chloromethyl)ether		X	
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran		X	
56-55-3	Benzo(a)anthracene		X	
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran		X	
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran		X	
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran		X	
57-24-9	Strychnine		X	
57465-28-8	3,3',4,4',5-Pentachlorobiphenyl (PCB 126)		X	
57653-85-7	1,2,3,6,7,8,-Hexachlorodibenzo(p)dioxin		X	
57-74-9	Chlordane		X	
581-42-0	2,6-Dimethylnaphthalene		X	
584-84-9	2,4-Toluene diisocyanate		X	
58-89-9	gamma-BHC (Lindane)		X	
591-50-4	Benzene, iodo-		X	
593-60-2	Bromoethene (Vinyl bromide)		X	
60-11-7	Dimethyl aminoazobenzene		X	
606-20-2	2,6-Dinitrotoluene		X	
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran		X	
608-93-5	Pentachlorobenzene		X	
61626-71-9	Dichloropentadiene		X	
624-83-9	Methyl isocyanate		X	
62-50-0	Ethyl methanesulfonate		X	
62-53-3	Aniline		X	
64-18-6	Formic acid (methanoic acid)		X	
65510-44-3	2',3,4,4',5-Pentachlorobiphenyl (PCB 123)		X	
65-85-0	Benzoic acid		X	
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran		X	
69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)		X	
70-30-4	Hexachlorophene		X	
70362-50-4	3,4,4',5-Tetrachlorobiphenyl (PCB 81)		X	
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran		X	
72-43-5	Methoxychlor		X	
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran		X	
74472-37-0	2,3,4,4',5-Pentachlorobiphenyl (PCB 114)		X	
74-88-4	Iodomethane		X	
74-95-3	Methylene bromide		X	
74-97-5	Bromochloromethane		X	
75-25-2	Bromoform		X	

CAS #	COPC	Feed Organic	PIC	Feed/PIC ^(a)
75-29-6	2-Chloropropane		X	
75-44-5	Phosgene (hydrogen phosphide)		X	
76-01-7	Pentachloroethane		X	
764-41-0	1,4-Dichloro-2-butene		X	
76-44-8	Heptachlor		X	
765-34-4	Glycidylaldehyde		X	
77-47-4	Hexachlorocyclopentadiene		X	
77-78-1	Dimethyl sulfate		X	
80-62-6	Methyl methacrylate		X	
822-06-0	Hexamethylene-1,5-diisocyanate		X	
823-40-5	Toluene-2,6-diamine		X	
82-68-8	Pentachloronitrobenzene (PCNB)		X	
832-69-9	1-Methylphenanthrene		X	
85-44-9	Phthalic anhydride (1,2-benzenedicarboxylic anhydride)		X	
87-61-6	1,2,3-Trichlorobenzene		X	
88-74-4	o-Nitroaniline (2-nitroaniline)		X	
90-04-0	o-Anisidine		X	
90-12-0	1-Methylnaphthalene		X	
91-22-5	Quinoline		X	
91-57-6	2-Methylnaphthalene		X	
91-94-1	3,3'-Dichlorobenzidine		X	
924-16-3	N-Nitroso-di-n-Buetylamine		X	
94-59-7	Safrole (5-(2-Propenyl)-1,3-benzodioxole)		X	
94-75-7	2,4-D		X	
95-49-8	o-Chlorotoluene		X	
95-53-4	o-Toluidine		X	
95-63-6	1,2,4-Trimethyl benzene		X	
95-94-3	1,2,4,5-Tetrachlorobenzene		X	
96-12-8	1,2-Dibromo-3-chloropropane		X	
96-18-4	1,2,3-Trichloropropane		X	
96-45-7	Ethylene thiourea		X	
97-63-2	Ethyl methacrylate		X	
98-01-1	Furfural		X	
98-06-6	tert-Butyl benzene		X	
98-07-7	Benzotrichloride		X	
98-83-9	Methyl styrene (mixed isomers)		X	
99-35-4	1,3,5-Trinitrobenzene		X	
99-65-0	1,3-Dinitrobenzene		X	
99-87-6	p-Cymene		X	
105-67-9	2,4-Dimethylphenol		X	

(a) Feed/PIC designation from Ref. 9.15, Attachment A

Table A-3 – WTP Inorganic COPCs

CAS #	COPC	Feed	Stack
7440-22-4	Ag	X	
7429-90-5	Al	X	
7440-38-2	As	X	
7440-39-3	Ba	X	
7440-41-7	Be	X	
24959-67-9	Br	X	
7440-43-9	Cd	X	
16887-00-6	Cl	X	
57-12-5	CN	X	
7440-48-4	Co	X	
7440-47-3	Cr	X	
7440-50-8	Cu	X	
16984-48-8	F	X	
7439-89-6	Fe	X	
7439-97-6	Hg	X	
7439-93-2	Li	X	
7439-95-4	Mg	X	
7439-96-5	Mn	X	
7439-98-7	Mo	X	
7440-23-5	Na	X	
7664-41-7	NH3	X	
7440-02-0	Ni	X	
14797-65-0	NO2	X	
14797-55-8	NO3	X	
7723-14-0	P	X	
7439-92-1	Pb	X	
14265-44-2	PO4	X	
7440-16-6	Rh	X	
7704-34-9	S	X	
7440-36-0	Sb	X	
7782-49-2	Se	X	
7440-31-5	Sn	X	
14808-79-8	SO4	X	
7440-24-6	Sr	X	
7440-25-7	Ta	X	
7440-28-0	Tl	X	
7440-61-1	UTOTAL	X	
7440-62-2	V	X	
7440-33-7	W	X	
7440-65-5	Y	X	
7440-66-6	Zn	X	
7440-67-7	Zr	X	
593-74-8	Dimethyl Mercury	X	
10102-44-0	Nitrogen dioxide		X

CAS #	COPC	Feed	Stack
124-38-9	Carbon dioxide		X
630-08-0	Carbon monoxide		X
10028-15-6	Ozone		X
7446-09-5	Sulfur dioxide		X
7647-01-0	Hydrogen chloride		X
7664-39-3	Hydrogen Fluoride		X
7782-41-4	Fluorine gas		X
7782-50-5	Chlorine		X
22967-92-6	Methyl mercury		X
N/A	Particulate matter		X

Attachment B - Radionuclide COPC Specific Activities

The following table of specific activities for WTP radionuclide COPCs was extracted from the *Risk Assessment Information System* database (Ref. 10.1)

Radionuclide	Specific Activity (Ci/g)
Ac-227	7.24E+01
Am-241	3.43E+00
Am-243	2.00E-01
Ba-137m	5.34E+08
C-14	4.48E+00
Cd-113m	2.23E+02
Cm-242	3.31E+03
Cm-243	5.05E+01
Cm-244	8.09E+01
Co-60	1.11E+03
Cs-134	1.28E+03
Cs-137	8.59E+01
Eu-152	1.73E+02
Eu-154	2.69E+02
Eu-155	4.82E+02
H-3	9.62E+03
I-129	1.75E-04
Nb-93m	2.39E+02
Ni-59	5.91E-02
Ni-63	5.59E+01
Np-237	7.04E-04
Pa-231	4.72E-02
Pu-238	1.71E+01
Pu-239	6.20E-02
Pu-240	2.27E-01
Pu-241	1.03E+02
Pu-242	3.94E-03
Ra-226	9.89E-01
Ra-228	2.73E+02
Ru-106	3.27E+03
Sb-125	1.03E+03
Se-79	1.52E-02
Sm-151	2.62E+01
Sn-126	1.22E-02
Sr-90	1.37E+02
Tc-99	1.70E-02
Th-229	2.13E-01

Radionuclide	Specific Activity (Ci/g)
Th-232	1.10E-07
U-232	2.24E+01
U-233	9.64E-03
U-234	6.22E-03
U-235	2.16E-06
U-236	6.47E-05
U-238	3.36E-07
Y-90	5.38E+05
Zr-93	2.49E-03

Attachment C – Media File 24590-RMCD-04955

Excel spreadsheets used in this calculation are attached to Media File 24590-RMCD-04955.

Attachment D- Extracted Radionuclide Properties from NuDat 2.6 Database (Ref. 10.6)

Ground and isomeric state information for $^{237}_{93}\text{Np}$				
E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	5/2+	44.8746	2.144E+6 y 7	α : 100.00 % SF \leq 2E-10 %

Ground and isomeric state information for $^{238}_{94}\text{Pu}$				
E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	0+	46.1661	87.7 y 1	α : 100.00 % SF : 1.9E-7 %

Ground and isomeric state information for $^{239}_{94}\text{Pu}$				
E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	1/2+	48.5912	24110 y 30	α : 100.00 % SF : 3.E-10 %

Ground and isomeric state information for $^{240}_{94}\text{Pu}$				
E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	0+	50.1283	6561 y 7	α : 100.00 % SF : 5.7E-6 %

Ground and isomeric state information for $^{241}_{95}\text{Am}$				
E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	5/2-	52.9373	432.6 y 6	α : 100.00 % SF : 4E-10 %

Ground and isomeric state information for $^{242}_{94}\text{Pu}$				
E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	0+	54.7196	3.75E+5 y 2	α : 100.00 % SF : 5.5E-4 %

Ground and isomeric state information for $^{243}_{95}\text{Am}$				
E(level) (MeV)	J π	Δ (MeV)	T $_{1/2}$	Decay Modes
0.0	5/2-	57.1774	7370 y 40	α : 100.00 % SF : 3.7E-9 %

Ground and isomeric state information for $^{243}_{96}\text{Cm}$				
E(level) (MeV)	J π	Δ (MeV)	T $_{1/2}$	Decay Modes
0.0	5/2+	57.1849	29.1 y 1	α : 99.71 % ϵ : 0.29 % SF : 5.3E-9 %

Ground and isomeric state information for $^{244}_{96}\text{Cm}$				
E(level) (MeV)	J π	Δ (MeV)	T $_{1/2}$	Decay Modes
0.0	0+	58.4550	18.1 y 1	α : 100.00 % SF : 1.4E-4 %
1.0402	6+	59.4952	34 ms 2	IT : 100.00 %

Attachment E- Phase Emissions Sensitivity Analysis for ¹⁴C and ³H

In order to check that Assumptions 6.2.6 and 6.2.7 conservatively assume that ¹⁴C and ³H (respectively) are emitted entirely in the vapor phase, the results using the methodologies for particle emissions and vapor emissions were compared using the worksheet "14C and 3H Sensitivity" in "DFLAW Radionuclide COPC Emissions Estimate.xlsx". For the sensitivity analysis, all radionuclide COPCs, except ¹⁴C and ³H, were removed from the workset and the calculation was completed for particle emissions and vapor emissions. The results are shown in Figure E-1 below. The results show that assuming unabated vapor emissions greatly exceeds unabated particle emissions for ¹⁴C (Cell R5 > Cell L5) and are equal for ³H (Cell R6 = Cell L6).

Figure E-1 - Phase Emissions Sensitivity Analysis for ¹⁴C and ³H

										Entrained Emissions			Vapor Emissions			ACV Exhaust System Emissions			APQs				
CAS #	COPC	Tank Farms Average ratio of COPC <i>i</i> , in mCi COPC / g Na	Specific Activity of COPC <i>i</i> , in Ci/g	Maximum feed vector batch activity of COPC <i>i</i> , in Ci	Maximum feed vector batch activity of COPC <i>i</i> , in Ci	Maximum feed vector batch mass of COPC <i>i</i> , in g	Maximum feed vector batch mass fraction of COPC <i>i</i>	Maximum feed vector batch concentration of COPC <i>i</i> , in g/L	Entrained mass flowrate of COPC <i>i</i> , in g/min	Unabated activity of COPC <i>i</i> emitted per year, in Ci/year	Abated activity of COPC <i>i</i> emitted per year, in Ci/year	Mass of COPC <i>i</i> flushed to DEP-VSL-0001 annually, in g/yr	Unabated activity of COPC <i>i</i> emitted per year, in Ci/year	Abated activity of COPC <i>i</i> emitted per year, in Ci/year	Unabated activity of COPC <i>i</i> emitted per year from the ACV Exhaust system, in Ci/year	Abated activity of COPC <i>i</i> emitted per year from the ACV Exhaust system (Single-stage HEPA), in Ci/year	Abated activity of COPC <i>i</i> emitted per year from the ACV Exhaust system (Dual-stage HEPA), in Ci/year	APQs - DEP System, in Ci/yr					
	<i>i</i>	<i>r_i</i>	<i>SA_i</i>	<i>A_i</i>	<i>A_i</i>	<i>m_i</i>	<i>X_i</i>	<i>C_i</i>	<i>m̄_{i,entrained}</i>	<i>Ā_{i,unabated}</i>	<i>Ā_{i,abated}</i>	<i>m̄_{i,flush}</i>	<i>Ā_{i,unabated}</i>	<i>Ā_{i,abated}</i>	<i>Ā_{i,unabated,ACV}</i>	<i>Ā_{i,abated,ACV}</i>	<i>Ā_{i,abated,ACV}</i>	<i>APQ_i</i>					
Ref. 9.1	Ref. 9.1	Ref. 9.2	Input 2.1	Equation 1	Adjusted values per Section 7.1.1.1 in grey	Equation 8	Equation 10	Equation 11	Equation 13	Equation 14	Equation 15	Equation 17	Equation 18 (14C) or Equation 21 (3H)	Same as <i>Ā_{i,unabated}</i>	Equation 22	Apply DF of 2000 for entrained emissions and DF of 1 for vapor emissions	Apply DF of 200,000 for entrained emissions and DF of 1 for vapor emissions	Equation 23 (entrained) Equation 25 (vapor)	Additional Inputs and Assumptions				
14762-75-5	14C	1.11E-05	4.48E+00	7.84E-01	7.84E-01	1.75E-01	3.35E-10	4.62E-07	1.80E-10	4.24E-04	2.12E-09	4.07E-02	1.82E-01	1.82E-01	3.04E-02	3.04E-02	3.04E-02	1.82E-01	Maximum batch amount of Na in DFLAW Bounding Feed Vector, in kmol	<i>n_{Na,max}</i>	Attachment G	3063.6321	
10028-17-8	3H	5.69E-05	9.52E+03	4.01E+00	4.01E+00	4.17E-04	7.99E-13	1.10E-09	4.29E-13	2.17E-03	1.09E-08	9.70E-05	2.17E-03	2.17E-03	3.62E-04	3.62E-04	3.62E-04	9.33E-01	Molecular weight of sodium, in kg/kmol	<i>MW_{Na}</i>	Input 2.5	22.9898	
																			Average total feed vector batch volume, in gal	<i>V_{batch,avg}</i>	Attachment G	100152.8804	
																			Average total vector batch density, in g/cc	<i>ρ_{batch,avg}</i>	Attachment G	1.3773	
																			Average total feed vector batch mass, in g	<i>m_{batch,avg}</i>	Equation 9	522090816.9	
																			Total mass flowrate of the DVP system except for the evaporator, in lb/hr	<i>m̄_{evap,vent}</i>	Assumption 6.1.4	528	
																			Entrainment factor for DEP vessels, in g entrained material / g air	<i>EF_{ves}</i>	Input 2.3 Assumption 6.2.3	4.00E-05	
																			Mass flowrate of the evaporator vent stream, in lb/hr	<i>m̄_{evap,vent}</i>	Assumption 6.1.4	50	
																			Entrainment factor for DEP evaporator, in g entrained material / g air	<i>EF_{evap}</i>	Input 2.20 Assumption 6.2.30	1.00E-03	
																			Total mass flowrate of entrained material, in g/min	<i>m̄_{tot,entrained}</i>	Equation 12	5.38E-01	
																			Decontamination Factor of primary HEPA filter	<i>DF_{HEPA,primary}</i>	Assumption 6.2.10	2000	
																			Decontamination Factor of secondary HEPA filter	<i>DF_{HEPA,secondary}</i>	Assumption 6.2.10	100	
																			Total volume of LAW feed line flush, in gal	<i>V_{flush}</i>	Input 2.4, Assumption 6.1.3	1500	
																			Flush Dilution Factor	<i>Dilution Factor</i>	Assumption 6.1.2	0.033333333	
																			Volume of residual feed in a LAW feed line flush, in L	<i>V_{residual,feed}</i>	Equation 16	189.25	
																			Frequency of LAW feed line flush, in 1/hr	<i>F_{flush}</i>	Assumption 6.1.3	0.053191489	
																			Evaporator MDR	<i>MDR_{evap,condenser}</i>	Assumption 6.1.35	6.00E-01	
																			Primary Condenser MDR	<i>MDR_{prim,condenser}</i>	Assumption 6.1.35	1.75E-02	
																			Inter-condenser MDR	<i>MDR_{int,condenser}</i>	Assumption 6.1.35	2.22E-01	
																			Combined MDR	<i>MDR_{combined}</i>	Equation 20	2.33E-03	
																			Volumetric flowrate of DEP evaporator feed stream, in gpm	<i>V_{evap,feed}</i>	Assumption 6.1.7	10	
																			Annual volume processed through DEP evaporator, L	<i>V_{evap,throughput}</i>	Equation 24	19893960	

Attachment F – Stream Properties Extracted from PIBOD Runs

The values for the mass flowrate of TOC in the LAW melter feed stream (LFP04) were extracted from the PIBOD model run results documented in calculation 24590-WTP-M4C-V11T-00012 (Ref. 9.23). The model run results for Ref. 9.23 are contained in 24590-RMVD-00357-02, Folder “*PIBOD Runs*”.

Table F-1 – Stream LFP04 TOC

PIBOD Model Run #	TOC (kg/hr)
1	10.92
2	10.23
3	9.99
4	10.50
5	12.43
6	9.55
7	12.46
8	11.00
9	11.19
10	7.79
11	7.75
12	15.29
13	11.08
14	10.22
15	13.80
16	12.35
17	11.41
18	12.32
19	9.79
20	8.00
21	8.20
22	14.06
23	11.75
Average	10.96
Maximum	15.29

The maximum value of 15.29 kg/hr will be rounded up to 20 kg/hr for use in this calculation as variable $TOC_{MF,max}$.

The values for the NH_4^+ and total mass flowrate in LVP21 were extracted from the PIBOD model run results documented in calculation 24590-WTP-M4C-V11T-00012 (Ref. 9.23). The model run results for Ref. 9.23 are contained in 24590-RMVD-00357-02, Folder “*PIBOD Runs*”. The model runs report ammonia in the aqueous phase as the ammonium ion (NH_4^+), therefore the amount of NH_3 transferred in LVP21 is estimated using the results for NH_4^+ . The mass fraction of NH_4^+ in LVP21 was calculated by dividing the NH_4^+ mass flowrate by the total mass flowrate.

Table F-2 – Stream LVP21 NH_3 Mass Fraction

PIBOD Model Run #	NH_4^+ (kg/hr)	Total (kg/hr)	Mass Fraction
1	0.271	5.292	0.0511
2	0.251	4.903	0.0511
3	0.261	5.120	0.0510
4	0.269	5.254	0.0511
5	0.331	6.473	0.0511
6	0.244	4.776	0.0511
7	0.332	6.489	0.0511
8	0.288	5.636	0.0511
9	0.295	5.770	0.0511
10	0.195	3.816	0.0511
11	0.204	3.993	0.0512
12	0.385	7.516	0.0512
13	0.298	5.838	0.0511
14	0.273	5.333	0.0511
15	0.359	7.014	0.0511
16	0.327	6.403	0.0511
17	0.289	5.662	0.0510
18	0.317	6.204	0.0511
19	0.254	4.974	0.0511
20	0.210	4.128	0.0510
21	0.216	4.245	0.0510
22	0.368	7.207	0.0511
23	0.300	5.875	0.0511
Average	0.284	5.562	0.0511
Maximum	0.385	7.516	0.0512

The maximum value of 0.0512 will be rounded up to 0.06 for use in this calculation as variable x_{LVP21, NH_3} .

The values for mercury in the SBS condensate transfer stream (RLD21) were extracted from the PIBOD model run results documented in calculation 24590-WTP-M4C-V11T-00012 (Ref. 9.23). The model run results for Ref. 9.23 are contained in 24590-RMVD-00357-02, Folder “*PIBOD Runs*”.

Table F-3 – Stream RLD21 Hg

PIBOD Model Run #	Hg (kg/hr)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0

Attachment G – DFLAW Bounding Feed Vector Batch Properties

The following table shows the values extracted for each batch in the DFLAW Bounding Feed Vector included as part of Ref. 9.2. These values were calculated in Excel Spreadsheet “*Bounding_DFLAW-batches-to-wtp_TOTALS.xlsx*” Worksheet “*TOTALS*”.

Date	Batch #	Batch Volume	Batch Density	Sodium	TOC	Oxalate (C2O4-2)	Adjusted TOC (TOC+Oxalate)
		Gallons	g/cc	kmol	kmol	kmol	kg
							Equation 21
1/14/2022 15:36	1	100084	1.32225	3059.52	1.24E+02	4.07E+00	1582.14
1/31/2022 14:44	2	100100	1.32225	3060.01	1.24E+02	4.07E+00	1582.39
2/19/2022 2:20	3	100069	1.32225	3059.05	1.24E+02	4.07E+00	1581.89
3/9/2022 13:16	4	100068	1.32225	3059.03	1.24E+02	4.07E+00	1581.89
3/27/2022 9:04	5	100050	1.32225	3058.49	1.24E+02	4.07E+00	1581.61
4/15/2022 3:08	6	100167	1.32225	3062.06	1.24E+02	4.07E+00	1583.45
5/3/2022 23:52	7	100097	1.32225	3059.92	1.24E+02	4.07E+00	1582.35
5/21/2022 6:36	8	100051	1.32225	3058.50	1.24E+02	4.07E+00	1581.61
6/8/2022 19:52	9	100129	1.32225	3060.89	1.24E+02	4.07E+00	1582.85
6/27/2022 1:44	10	100151	1.32225	3061.57	1.24E+02	4.07E+00	1583.20
7/15/2022 7:52	11	100219	1.32225	3063.63	1.24E+02	4.08E+00	1584.27
9/2/2022 15:04	12	100006	1.36606	3045.48	1.12E+02	4.53E+00	1454.71
9/20/2022 18:44	13	100075	1.39020	3041.96	1.06E+02	4.78E+00	1386.30
10/9/2022 11:28	14	100220	1.39144	3046.05	1.06E+02	4.80E+00	1384.73
10/28/2022 7:20	15	100339	1.39177	3049.59	1.06E+02	4.81E+00	1385.43
11/16/2022 1:08	16	100127	1.39180	3043.13	1.05E+02	4.80E+00	1382.42
12/4/2022 15:52	17	100065	1.39180	3041.26	1.05E+02	4.80E+00	1381.55
12/23/2022 16:32	18	100072	1.39181	3041.47	1.05E+02	4.80E+00	1381.65
1/10/2023 18:36	19	100103	1.39181	3042.40	1.05E+02	4.80E+00	1382.07
1/29/2023 14:16	20	100087	1.39181	3041.93	1.05E+02	4.80E+00	1381.86
2/17/2023 5:04	21	100078	1.39181	3041.63	1.05E+02	4.80E+00	1381.72
3/9/2023 5:12	22	100253	1.39107	3043.71	9.79E+01	4.98E+00	1295.52
3/28/2023 3:44	23	100340	1.38954	3039.58	8.18E+01	5.34E+00	1110.82
4/16/2023 11:12	24	100288	1.38943	3037.52	8.06E+01	5.36E+00	1096.67
5/4/2023 21:48	25	100019	1.38940	3029.28	8.01E+01	5.36E+00	1090.41
5/23/2023 1:20	26	100009	1.38940	3028.97	8.00E+01	5.36E+00	1090.16
6/10/2023 6:00	27	100192	1.38940	3034.50	8.02E+01	5.37E+00	1092.11
6/28/2023 20:40	28	100058	1.38940	3030.45	8.01E+01	5.36E+00	1090.65
7/18/2023 5:04	29	100146	1.38940	3033.09	8.02E+01	5.36E+00	1091.60
8/5/2023 0:12	30	100031	1.38940	3029.63	8.01E+01	5.36E+00	1090.36
8/23/2023 14:12	31	100185	1.38940	3034.28	8.02E+01	5.37E+00	1092.03
9/12/2023 14:44	32	100094	1.39360	3030.48	8.46E+01	5.47E+00	1147.95
10/1/2023 2:28	33	100287	1.40067	3034.58	9.24E+01	5.65E+00	1246.16
10/19/2023 22:40	34	100230	1.40113	3032.74	9.29E+01	5.66E+00	1251.69
11/7/2023 6:04	35	100112	1.40125	3029.13	9.29E+01	5.66E+00	1251.83
12/13/2023 11:12	36	100176	1.40125	3031.07	9.30E+01	5.66E+00	1252.72
1/1/2024 10:24	37	100052	1.40125	3027.31	9.29E+01	5.65E+00	1251.18
1/19/2024 19:08	38	100218	1.40126	3032.35	9.30E+01	5.66E+00	1253.27
2/7/2024 4:56	39	100282	1.40126	3034.27	9.31E+01	5.67E+00	1254.06
2/27/2024 16:00	40	100038	1.40197	3029.28	9.39E+01	5.88E+00	1268.69
3/16/2024 1:40	41	100098	1.40499	3041.70	9.80E+01	6.86E+00	1341.86
4/4/2024 1:08	42	100072	1.40550	3042.92	9.86E+01	7.03E+00	1353.15
4/23/2024 2:00	43	100253	1.40558	3048.74	9.89E+01	7.07E+00	1357.29
5/12/2024 3:48	44	100048	1.40558	3042.53	9.87E+01	7.05E+00	1354.62
5/31/2024 1:56	45	100011	1.40559	3041.39	9.86E+01	7.05E+00	1354.13
6/18/2024 21:36	46	100155	1.40559	3045.78	9.88E+01	7.06E+00	1356.09
7/7/2024 3:12	47	100088	1.40559	3043.76	9.87E+01	7.06E+00	1355.19
7/26/2024 0:32	48	100338	1.40559	3051.36	9.90E+01	7.07E+00	1358.58
8/14/2024 0:28	49	100138	1.40559	3045.27	9.88E+01	7.06E+00	1355.87
9/4/2024 2:04	50	100167	1.39834	3044.47	9.33E+01	6.46E+00	1276.21
9/22/2024 5:56	51	100204	1.37503	3042.25	7.56E+01	4.76E+00	1022.36
10/10/2024 12:56	52	100098	1.37183	3039.10	7.30E+01	4.58E+00	987.18
10/28/2024 19:08	53	100108	1.37134	3039.47	7.26E+01	4.56E+00	981.98
11/16/2024 17:40	54	100071	1.37132	3038.36	7.26E+01	4.56E+00	981.46
12/4/2024 18:16	55	100255	1.37131	3043.94	7.27E+01	4.57E+00	983.18
12/22/2024 22:52	56	100248	1.37131	3043.73	7.27E+01	4.57E+00	983.11
1/10/2025 10:44	57	100075	1.37131	3038.47	7.26E+01	4.56E+00	981.41
1/28/2025 7:56	58	100172	1.37131	3041.44	7.27E+01	4.57E+00	982.36
2/15/2025 17:16	59	100238	1.37131	3043.43	7.27E+01	4.57E+00	983.01
3/7/2025 10:36	60	100075	1.37333	3037.34	6.33E+01	4.54E+00	869.03
3/24/2025 2:08	61	100143	1.37769	3035.41	4.25E+01	4.52E+00	618.85
4/11/2025 16:48	62	100228	1.37807	3037.31	4.06E+01	4.53E+00	596.34
4/30/2025 7:20	63	100173	1.37814	3035.50	4.02E+01	4.53E+00	591.21
5/17/2025 22:12	64	100241	1.37815	3037.55	4.02E+01	4.53E+00	591.44
6/5/2025 4:04	65	100299	1.37815	3039.29	4.02E+01	4.53E+00	591.71
6/23/2025 11:56	66	100004	1.37815	3030.38	4.01E+01	4.52E+00	589.97

CALCULATION SHEET

Date	Batch #	Batch Volume	Batch Density	Sodium	TOC	Oxalate (C2O4-2)	Adjusted TOC (TOC+Oxalate)
		Gallons	g/cc	kmol	kmol	kmol	kg
							Equation 21
7/11/2025 11:20	67	100279	1.37815	3038.70	4.02E+01	4.53E+00	591.59
7/29/2025 15:52	68	100299	1.37815	3039.30	4.02E+01	4.53E+00	591.71
8/17/2025 5:52	69	100330	1.37815	3040.25	4.02E+01	4.53E+00	591.89
9/6/2025 12:12	70	100162	1.37713	3013.32	3.76E+01	4.42E+00	557.79
9/24/2025 19:40	71	100158	1.37397	2947.14	3.01E+01	4.15E+00	461.07
10/12/2025 21:04	72	100234	1.37365	2942.92	2.94E+01	4.13E+00	452.16
10/31/2025 5:32	73	100243	1.37359	2941.85	2.92E+01	4.13E+00	450.27
11/17/2025 10:28	74	100106	1.37359	2937.77	2.92E+01	4.12E+00	449.60
12/5/2025 20:56	75	100344	1.37358	2944.73	2.93E+01	4.13E+00	450.64
12/23/2025 7:28	76	100019	1.37358	2935.19	2.92E+01	4.12E+00	449.18
1/10/2026 6:56	77	100117	1.37358	2938.09	2.92E+01	4.12E+00	449.62
1/28/2026 13:00	78	100028	1.37358	2935.48	2.92E+01	4.12E+00	449.22
2/14/2026 21:12	79	100078	1.37358	2936.92	2.92E+01	4.12E+00	449.44
3/7/2026 14:44	80	100025	1.37388	2963.89	5.16E+01	4.47E+00	727.67
3/26/2026 21:40	81	100223	1.37442	3028.37	9.76E+01	5.60E+00	1306.88
4/14/2026 7:04	82	100056	1.37444	3026.39	9.98E+01	5.67E+00	1335.27
5/3/2026 10:00	83	100173	1.37445	3030.95	1.01E+02	5.71E+00	1347.03
5/22/2026 7:24	84	100293	1.37445	3034.62	1.01E+02	5.72E+00	1349.07
6/10/2026 22:20	85	100212	1.37445	3032.20	1.01E+02	5.72E+00	1348.12
7/1/2026 1:40	86	100047	1.37445	3027.21	1.01E+02	5.71E+00	1345.91
7/23/2026 9:00	87	100350	1.37445	3036.36	1.01E+02	5.72E+00	1349.98
8/7/2026 22:20	88	100310	1.37445	3035.14	1.01E+02	5.72E+00	1349.44
8/28/2026 1:20	89	100084	1.37445	3028.33	1.01E+02	5.71E+00	1346.41
9/17/2026 22:44	90	100116	1.37176	2977.84	9.17E+01	5.78E+00	1240.42
10/9/2026 18:48	91	100210	1.36297	2812.67	6.24E+01	6.11E+00	896.32
11/3/2026 3:44	92	100306	1.36283	2812.72	6.20E+01	6.12E+00	891.76
11/25/2026 12:24	93	100003	1.36269	2801.38	6.13E+01	6.11E+00	883.29
12/20/2026 13:08	94	100309	1.36268	2809.84	6.15E+01	6.13E+00	885.80
1/13/2027 17:04	95	100116	1.36268	2804.41	6.14E+01	6.11E+00	884.01
2/7/2027 15:16	96	100098	1.36268	2803.89	6.14E+01	6.11E+00	883.85
4/26/2027 20:04	97	100026	1.36268	2801.89	6.13E+01	6.11E+00	883.21
5/21/2027 16:24	98	100061	1.36268	2802.86	6.13E+01	6.11E+00	883.52
6/11/2027 9:56	99	100258	1.35727	2754.20	7.59E+01	5.02E+00	1031.80
6/30/2027 11:28	100	100340	1.35614	2745.17	7.89E+01	4.80E+00	1063.29
7/18/2027 12:44	101	100053	1.35599	2735.83	7.91E+01	4.76E+00	1064.37
8/5/2027 10:28	102	100073	1.35599	2736.37	7.91E+01	4.76E+00	1064.66
8/24/2027 10:40	103	100244	1.35599	2741.00	7.93E+01	4.77E+00	1066.55
9/9/2027 15:44	104	100236	1.35599	2740.79	7.92E+01	4.77E+00	1066.47
9/27/2027 17:52	105	100039	1.35599	2735.42	7.91E+01	4.76E+00	1064.38
10/15/2027 17:36	106	100059	1.35599	2735.96	7.91E+01	4.76E+00	1064.59
11/3/2027 14:04	107	100232	1.35599	2740.69	7.92E+01	4.77E+00	1066.43
11/21/2027 13:40	108	100114	1.35599	2737.46	7.92E+01	4.77E+00	1065.18
12/11/2027 4:16	109	100232	1.37790	2895.17	6.98E+01	4.37E+00	943.22
12/29/2027 12:20	110	100178	1.38465	2941.23	6.68E+01	4.27E+00	905.29
1/15/2028 19:16	111	100233	1.38521	2946.76	6.66E+01	4.27E+00	902.73
2/3/2028 20:16	112	100227	1.38529	2947.15	6.66E+01	4.26E+00	902.25
5/15/2028 3:24	113	100263	1.38530	2948.29	6.66E+01	4.27E+00	902.51
6/1/2028 8:08	114	100017	1.38530	2941.07	6.64E+01	4.26E+00	900.30
6/19/2028 13:24	115	100177	1.38530	2945.76	6.66E+01	4.26E+00	901.73
7/8/2028 4:24	116	100083	1.38530	2943.00	6.65E+01	4.26E+00	900.88
7/27/2028 5:56	117	100008	1.38530	2940.79	6.64E+01	4.25E+00	900.21
8/13/2028 7:52	118	100163	1.38530	2945.35	6.65E+01	4.26E+00	901.60
9/2/2028 21:56	119	100036	1.39903	3014.39	6.41E+01	4.29E+00	873.02
9/21/2028 9:00	120	100052	1.40051	3022.70	6.39E+01	4.29E+00	870.19
10/9/2028 19:24	121	100049	1.40080	3024.15	6.38E+01	4.29E+00	869.59
10/29/2028 17:56	122	100244	1.40082	3030.17	6.39E+01	4.30E+00	871.25
11/15/2028 20:56	123	100100	1.40082	3025.82	6.38E+01	4.30E+00	869.98
12/3/2028 23:48	124	100181	1.40082	3028.28	6.39E+01	4.30E+00	870.69
12/22/2028 22:52	125	100102	1.40082	3025.90	6.38E+01	4.30E+00	870.00
1/11/2029 6:08	126	100282	1.40082	3031.34	6.40E+01	4.30E+00	871.57
1/30/2029 3:32	127	100203	1.40082	3028.94	6.39E+01	4.30E+00	870.88
2/20/2029 14:40	128	100103	1.40033	3022.91	6.35E+01	4.30E+00	866.59
3/10/2029 7:56	129	100231	1.38545	2934.97	5.48E+01	4.39E+00	764.13
3/27/2029 17:24	130	100108	1.38219	2911.25	5.29E+01	4.41E+00	740.72
4/15/2029 13:52	131	100073	1.38186	2908.21	5.26E+01	4.41E+00	738.19
5/3/2029 14:52	132	100117	1.38181	2909.18	5.26E+01	4.41E+00	738.18
5/21/2029 20:52	133	100048	1.38180	2907.12	5.26E+01	4.41E+00	737.62
6/8/2029 13:12	134	100149	1.38180	2910.07	5.27E+01	4.41E+00	738.37
6/26/2029 6:20	135	100098	1.38180	2908.57	5.26E+01	4.41E+00	737.98
7/13/2029 19:36	136	100233	1.38180	2912.46	5.27E+01	4.41E+00	738.99

CALCULATION SHEET

Date	Batch #	Batch Volume	Batch Density	Sodium	TOC	Oxalate (C2O4-2)	Adjusted TOC (TOC+Oxalate)
		Gallons	g/cc	kmol	kmol	kmol	kg
							Equation 21
8/1/2029 5:00	137	100303	1.38180	2914.54	5.27E+01	4.42E+00	739.50
8/22/2029 4:52	138	100106	1.38178	2919.02	5.17E+01	4.46E+00	728.05
9/8/2029 0:52	139	100104	1.38154	3013.58	4.31E+01	4.90E+00	635.37
9/26/2029 12:44	140	100048	1.38152	3019.76	4.24E+01	4.93E+00	627.42
10/19/2029 20:08	141	100317	1.38152	3029.80	4.23E+01	4.96E+00	627.31
11/7/2029 9:04	142	100058	1.38152	3022.09	4.22E+01	4.94E+00	625.57
11/25/2029 22:48	143	100149	1.38152	3024.89	4.22E+01	4.95E+00	626.11
12/13/2029 23:08	144	100027	1.38152	3021.21	4.22E+01	4.94E+00	625.34
1/1/2030 0:04	145	100180	1.38152	3025.82	4.22E+01	4.95E+00	626.30
1/19/2030 3:04	146	100268	1.38152	3028.47	4.23E+01	4.95E+00	626.85
2/5/2030 15:52	147	100293	1.38152	3029.24	4.23E+01	4.96E+00	627.01
2/26/2030 14:28	148	100328	1.38191	3031.24	4.37E+01	4.96E+00	643.91
3/17/2030 1:28	149	100286	1.38427	3035.47	5.24E+01	5.00E+00	749.11
4/7/2030 7:24	150	100338	1.38468	3037.81	5.40E+01	5.01E+00	768.71
4/24/2030 16:04	151	100146	1.38473	3032.10	5.41E+01	5.01E+00	769.55
5/12/2030 23:48	152	100064	1.38474	3029.63	5.40E+01	5.00E+00	769.14
5/31/2030 15:48	153	100091	1.38474	3030.47	5.41E+01	5.00E+00	769.40
6/19/2030 23:16	154	100099	1.38474	3030.71	5.41E+01	5.00E+00	769.46
7/8/2030 4:32	155	100022	1.38474	3028.37	5.40E+01	5.00E+00	768.87
7/25/2030 19:44	156	100136	1.38474	3031.82	5.41E+01	5.00E+00	769.75
8/13/2030 4:04	157	100331	1.38474	3037.72	5.42E+01	5.01E+00	771.24
9/1/2030 22:36	158	100334	1.38186	3038.46	5.06E+01	5.10E+00	730.02
9/30/2030 11:32	159	100057	1.37166	3032.12	3.77E+01	5.40E+00	582.91
10/17/2030 13:04	160	100073	1.37086	3032.67	3.68E+01	5.43E+00	571.90
11/5/2030 13:08	161	100242	1.37067	3037.81	3.66E+01	5.44E+00	570.12
11/22/2030 11:08	162	100228	1.37066	3037.40	3.66E+01	5.44E+00	569.90
12/10/2030 22:20	163	100019	1.37066	3031.06	3.65E+01	5.43E+00	568.67
12/29/2030 5:20	164	100099	1.37066	3033.47	3.65E+01	5.43E+00	569.12
1/17/2031 5:40	165	100056	1.37066	3032.17	3.65E+01	5.43E+00	568.87
2/3/2031 13:48	166	100116	1.37066	3034.01	3.65E+01	5.43E+00	569.22
2/22/2031 1:52	167	100031	1.37066	3031.43	3.65E+01	5.43E+00	568.73
3/11/2031 16:40	168	100210	1.37007	3000.82	3.87E+01	5.18E+00	589.07
3/29/2031 16:52	169	100310	1.36827	2883.17	4.59E+01	4.37E+00	656.70
4/16/2031 21:44	170	100194	1.36808	2863.34	4.69E+01	4.27E+00	665.83
5/5/2031 21:12	171	100100	1.36805	2858.12	4.70E+01	4.26E+00	666.76
5/22/2031 16:24	172	100136	1.36805	2859.06	4.70E+01	4.26E+00	667.07
6/9/2031 13:04	173	100030	1.36805	2855.98	4.70E+01	4.25E+00	666.38
6/27/2031 12:28	174	100137	1.36805	2859.04	4.70E+01	4.26E+00	667.10
7/15/2031 23:12	175	100070	1.36805	2857.12	4.70E+01	4.25E+00	666.65
8/2/2031 6:36	176	100285	1.36805	2863.26	4.71E+01	4.26E+00	668.08
8/20/2031 13:56	177	100218	1.36805	2861.36	4.71E+01	4.26E+00	667.64
	Average	100153	1.37726	2982.39	69.79	4.94	957.00
	Minimum	100003	1.32225	2735.42	29.16	4.07	449.18
	Maximum	100350	1.40559	3063.63	123.75	7.07	1584.27