Reviewed by Michael Overcash 5-15-11
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Glyphosate from PMIDA [1071-83-6]

CONTENTS OF FACTORY GATE TO FACTORY GATE

LIFE CYCLE INVENTORY SUMMARY

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Peer reviews, name (date)	MR Overcash (5-30-2011)
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Additional notes	

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Products	glyphosate
Standard inputs	Oxygen, PMIDA

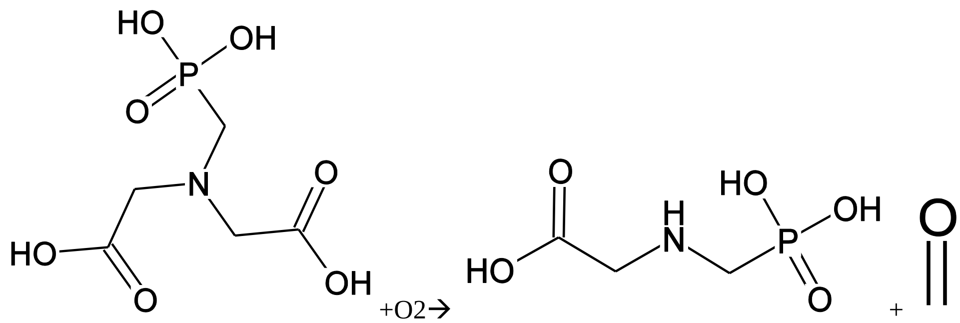
Methodology: Environmental Clarity gtg lci reports are based on industrial practice information, standard methods of engineering process design, and technical reviews. These reports are intended to be representative of industrial production based on the stated route.

Users of this report should cite: E. Griffing and M. Overcash, Chemical Life Cycle Database, www.environmentalclarity.com, 1999 - present.

Chemistry

Primary reaction:

$$C_5H_{10}O_6NP + \frac{1}{2} O_2 \rightarrow C_4H_8NO_4 + CO_2 + H_2CO \qquad (1)$$

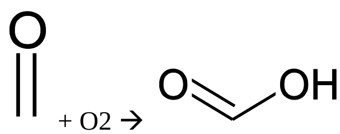


N-phosphonomethyliminodiacetic acid (PMIDA) + oxygen → glyphosate + formaldehyde + CO_2

Notes: glyphosate is the common name for (N-(phosphonomethyl)glycine)

Oxidation of formaldehyde:

$$H_2CO + \frac{1}{2} O_2 \rightarrow HCOOH \qquad (2)$$

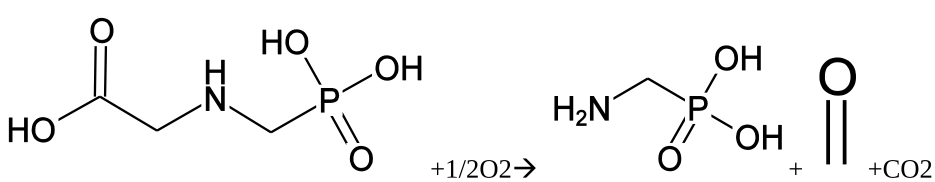


Formaldehyde + oxygen → formic acid

Notes: Depending on the catalyst and reaction conditions, this can proceed to different extents. We assume that 20% of formaldehyde is oxidized further. US 5,606,107 describes strategies for increasing oxidation of byproducts to CO2. Any unreacted formaldehyde must be sent to aerated waste treatment for further oxidation.

Side reactions: (oxidation of glyphosate)

$$C_4H_7NO_4 + 1/2O_2 \rightarrow \text{CH6N2PO3} + H_2CO + \text{CO2} \qquad (5)$$



Glyphosate+oxygen → aminomethylphosphonic acid + formaldehyde(7)

Notes:

Process Summary

Literature

Glyphosate is the active ingredient in a broad-spectrum herbicide often marketed as round-up. Popular formulations in commercial herbicides are as glyphosate salts. The most popular salt is isopropylammonium (Green, S. and Pohanish, R.P., 2007). Other salts are monoammonium, diammonium, and potassium (BCPC, 2010). These salts provide the primary function of increasing the solubility in water. The solubility of glyphosate is increased from 2 wt% in water to about 44 wt% in water when in the salt form. Typical commercial formulations are 2 to 30 wt% (US 7,049,270, 2006).

As of 2000, Monsanto was the largest producer of glyphosate. Production by competition was about 40,000 tonnes/yr (Woodburn, 2000). As of 2009, China had a capacity of 655,000 tonnes glyphosate /yr, and China produced about 70% of the world supply of technical grade glyphosate. Most of China's production is shipped to other countries to be formulated and marketed as an herbicide (R & M, 2011). Although some efficiency improvements may be achieved by producing the salt directly, we show production of the glyphosate acid and crystallizing as a product. The salts can then be formed from the solid glyphosate in a separate life cycle inventory gate-to-gate.

Glyphosate is produced by four routes (1) original Monsanto (2) new Monsanto, (3) Chinese chloracetic acid route, (4) Syngenta route (Bryant, 2003). The Monsanto routes and the Chinese chloracetic acid route all go through the intermediate iminodiacetic acid (IDA) and phosphonomethyl iminodiacetic acid (PMIDA). The differences are in production of the intermediate IDA. In world production, the primary starting point for IDA is diethyl amine (DEA). However, in China, 80% of the IDA capacity is currently from glycine (Yin, 2011). In this gtg, glyphosate acid is produced from PMIDA. In our gtg library, the disodium salt of IDA is produced from DEA.

In Monsanto's process, IDA is converted to PMIDA. PMIDA is converted to the isopropylamine salt (DSIDA). The overall yield of these steps is 85% (Woodburn, 2000). The conversion of IDA to PMIDA is 93% (see separate gtg report for PMIDA), and the conversion of PMIDA to glyphosate is 93%. The formation of the salt is assumed to be 100% efficient. US 7,049,270 gives a procedure for making the potassium salt, and there are no separation losses. Thus the overall yield in the set of gtgs is 85%. The overall yield from ethylene oxide (used to produce diethanolamine for IDA production) is 50% or lower (US 7,750,180). The reason for the low yield from ethylene oxide (<50%) is that the oxidative cleaving of the intermediate PMIDA, during which, one of the two acetic acid groups is cleaved, and is not recoverable (US 7,750,180).

PMIDA is fed to a reactor in an aqueous phase, and an oxygen source such as air or gaseous oxygen is sparged through the reactor. US 7,799,571 describes a series of three reactors. Oxygen is sparged through the reactors at different rates to achieve higher conversion of PMIDA. Total conversion is about 97 to 99.5%. In this gtg, we show a single reactor, and assume a conversion of 99%. After the reaction, catalyst (typically noble metal on carbon) is filtered then recycled, and the solution is sent to an evaporative crystallizer. In this gtg, we follow a crystallization scheme presented in US 7,799,571. After filtration, a portion of the reactor effluent is sent to an adiabatic vacuum crystallizer, and the remainder is sent to a thermal evaporative crystallizer. In this gtg, we assume that half is sent to each evaporator. The effluent is separated from the crystals by a centrifuge. Ten percent of the effluent is purged to prevent buildup of PMIDA, and the remainder is sent back to the crystallizer to recover glyphosate. Thus, substantially all of the water is evaporated in the crystallizer. The crystals from the centrifuge are dried and are considered technical grade. The size of the purge represents a trade-off between PMIDA content in product and recovery of glyphosate.

If the reaction time is long and / or the conditions are highly oxidizing, the PMIDA will be converted at a higher percentage of input. However, the product over-oxidizes glyphosate to aminomethylphosphonic acid (AMPA). Additionally, the glyphosate and AMPA can be methylated with the formaldehyde byproduct. Thus, there is a yield tradeoff between low conversion and high side product formation. Under commercial conditions, the rate constant for reaction of glyphosate with oxygen to that of PMIDA with oxygen is less than 0.017 (US 6,921,834). In the final reactor, about 7% of the PMIDA is converted. However, the ratio of glyphosate to PMIDA during this reactor is about 95 to 5. Thus, the conversion of glyphosate to AMPA is about 95/5*.017 = 0.32 * 7% = 2.2%. The overall conversion of glyphosate to

AMPA is assumed to be 2.5%. The overall yield is assumed to be 93%, and the losses to unreacted PMIDA and over-oxidized glyphosate are 1% and 2.5%, respectively. Thus, additional losses in the separation system are 3.5%.

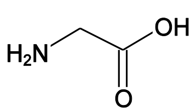
Table 1. Process parameters

	Reactor T	Reactor P, atm	Water, kg / kg PMIDA	O2, kg / kg PMIDA	Catalyst, kg/kg PMIDA	Reaction time	Notes
US 6,921,834	75	7	10 to 49		0.15		6
US 7,799,571	90	4	12 to 37	0.08-0.11 (0.55-0.83)	0.13 to 0.375		1,2,3,7
US 5,962,729	Preheated to 70 oC	4	190	2.8 (20 mol/mol)		Order of 20 minutes	
US 3,969,398	75 – 90 oC 90 in example	1 to 7 3.1 in example	25	1.4 (10 mol/mol)	0.05 to 0.2	3 hrs.	4
Used in this gtg	90	3.5	36	0.14 (1 mol/mol)	0.15	2 hrs	5

1. Exothermic with cooling
2. O2 source can be air, oxygen enriched air or pure oxygen
3. Per pass conversion in a series of reactors is 97 to 99.5%
4. Industrial separations not discussed. Water and byproducts were evaporated from product at vacuum.
5. The solubility of glyphosate is 2 wt% in water (Monig et al.). The water flow into the reactor is set so that the output is saturated with glyphosate.
6. Concentration of PMIDA specified as between 2 and 10wt% into oxidation reactor.
7. This corresponds to 60 to 90% utilization of O2 in primary reaction.

The oxidation reaction is exothermic and heat is removed by heat exchangers. The heat of reaction is estimated by a proxy reaction of glycine oxidation.

C2H5NO2 + ½ O2 → NH3 + CO2 + H_2CO



(s) +O2 → NH3(l) + CO2(g) + 

(g)

Glycine + oxygen → ammonia + carbon dioxide + formaldehyde

The effect of the –CH2COOH and -CH2HPO3 groups is neglected. The heat of reaction is -69.2-393.5-115.9– (-527 + 0) = -51.6 kJ/gmol. The heat of reaction for over-oxidation of glyphosate to AMPA is also 51.6 kJ/gmol.

The solubility of PMIDA (2 % at 75C and 6 % at 105C [6921834 p. 12 line 25]; 1 % at 25C, 4 % at 95C, 10 % at 150C [3,969,398 p. 2 line 36] is close to that of glyphosate (on mass basis) (1.01% at 20C, [Wikipedia]; 1.9 wt% Monig et al.). The ratio of PMIDA to glyphosate in the recycle is at least 1.5 and typically 5 to 8 times the ratio of PMIDA to glyphosate after the reaction (US 7,799,571, 2010). The purge (up to 10%) prevents buildup of PMIDA. In this gtg, the purge is 10% and the PMIDA concentration relative to glyphosate is 5 times the ratio after the reactor.

LCI design

PMIDA is fed as a 2.7 wt% aqueous solution. It is combined with an aqueous recycle stream, heated to 90 oC and fed to a reactor. Oxygen (100% stoichiometric excess) is bubbled through a continuous stirred tank reactor. The residence time is 2 hours, and mechanical mixing is used. The reactor effluent is filtered to recover catalyst. The liquid phase is split equally between two evaporators. The first evaporator utilizes vacuum to evaporate water adiabatically. The amount of water evaporated is calculated based on the temperature drop (90 oC to 35 oC), and is about 10%. The liquid passes through a filter to recover glyphosate, and the filtrate is recycled to the reactor. The remainder of the filtered reactor effluent is sent to a steam evaporator, where the majority of water is removed from the process. The concentrated stream exiting the evaporator is combined with glyphosate from the vacuum evaporator and solid glyphosate is recovered in a centrifuge. The liquid is returned to the thermal evaporator after a 10% purge to prevent buildup of PMIDA. The crystals from the centrifuge are dried and cooled to standard temperature.

Notes:

There is a large water flow into the reactor. Sending water through the vacuum evaporator saves energy by reducing the fresh water input. However, it is not clear how much of the filtered reactor effluent goes through this loop. The energy required for the thermal evaporation is 50 MJ/kg. If we put more through that evaporator, it could nearly double. However, expensive multi-effect evaporators could be used to reduce this (not sure if this would be used at this production volume).

From Green (via other source), the cradle-to-gate of glyphosate requires 454 MJ/kg), more than twice that of atrazine (190 MJ/kg)

References

BCPC (2010) *The Pesticide Manual*, 14th edition, see www.pesticidemanual.com for details.
Bryant, R.B. (2003) "Matching technical and market intelligence needs with resources," *Specialty Chemicals Magazine*, accessed online: http://www.agranova.co.uk/pdf/RJB_ChemSpec2003.pdf.
Green, S, and Pohanish, R.P. (2005) *Sittig's Handbook of Pesticides and Agricultural Chemicals*, William Andrew Publishing.
Monig, E. Zwidinger, R.A., Warner, M., Batten, R., Liverman, D., (date not found) Treatment technology for pesticide manufacturing effluenets: Glyphosate, Research Triangle Institute, Contract 68-02-3688.
R & M (2001) Research and Markets report accessed online http://www.researchandmarkets.com/reportinfo.asp?report_id=1082203&t=d&cat_id=
Ullmann's (year). *Ullmann's Encyclopedia of Industrial Chemistry*, ArticleName (Authors, article authors)
US 7,049,270 (2006) "Potassium Glypohsate Formulations," Awarded to Monsanto Technology LLC.
Woodburn, A.T. (2000) "Glyphosate: production, pricing and use worldwide," *Pest Management Science* **56**, pp 309-312.
Yin, G. (2011). Glyphosate: There Is No Substitute, url: http://www.farmchemicalsinternational.com/cropprotection/productfocus/?storyid=2997

Critical parameters

Conversion / Yield information from both reactors			
		Conversion of or Yield from PMIDA	Conversion of or Yield from Oxygen
Total conversion in reactor 1: (% of reactant entering the process that reacts)	From mass balance	99	60
Total per pass conversion in reactor 1: (% of reactant entering the reactor that reacts)	From mass balance	98	60
Total yield of reactor 1: (% yield ProductChem produced in the reactor based on reactant input to process)	From mass balance	99	81
Total yield of Process: (% yield produced by the overall process based on reactant input to process)	From mass balance	93	47
Notes:			

Product purity		
	Glyphosate	Comments
Used here	98.7	

Summary of LCI Information

Standard inputs					
UID	Name	Flow	Purity	Units	Comments
7782-44-7	Oxygen	199	-	[kg/hr]	
5994-61-6	PMIDA	1422	-	[kg/hr]	
	Total	1621		[kg/hr]	
Non-reacting inputs					
UID	Name	Flow	Purity	Units	Comments
7732-18-5	Water	2.84E+04	-	[kg/hr]	
	Total	2.84E+04		[kg/hr]	
Ancillary inputs					
UID	Name	Flow	Purity	Units	Comments
	Total	0		[kg/hr]	
Products					
UID	Name	Flow	Purity	Units	Comments
1071-83-6	glyphosate	1001	98.6	[kg/hr]	
	Total	1001		[kg/hr]	
Benign outflows					
UID	Name	Flow	Purity	Units	Comments
7732-18-5	Water	2.84E+04	-	[kg/hr]	
7782-44-7	Oxygen	79.0	-	[kg/hr]	
	Total	2.84E+04		[kg/hr]	

Process emissions							
UID	Name	Gas	Liquid	Solid	Solvent	Units	Comments
1071-83-6	glyphosate	0	50.8	0	0	[kg/hr]	
124-38-9	Carbon dioxide	277	0	0	0	[kg/hr]	
64-18-6	Formic acid	1.13	57.2	0	0	[kg/hr]	
50-00-0	Formaldehyde	1.49	150	0	0	[kg/hr]	
1066-51-9	aminomethylphosphonic acid	0	2.50	0	0	[kg/hr]	
5994-61-6	PMIDA	0	4.81	0	0	[kg/hr]	
	Total	280	266	0	0		

Mass balance	
Total inputs	3.00E+04
Total outflows	3.00E+04
Net input	-5.34

Energy use			
Energy type	Amount	Units	Comments
electricity	500	[MJ/hr]	Net electricity use at plant
heating steam	7.72E+04	[MJ/hr]	heating by steam (0.85 efficiency included)
Net input requirement	7.77E+04	[MJ/hr]	Net of energies input to system
cooling water	- 6.53E+04	[MJ/hr]	net cooling by cooling water
potential recovery	- 1.48E+04	[MJ/hr]	potential energy recovery (negative)
Net energy	6.29E+04	[MJ/hr]	Net input requirement - potential recovery

Process Diagram Interpretation Sheet

1) As much as possible, standard symbols are used for all unit processes.

2) Only overall input and output chemicals are labeled on these diagrams. All intermediate information is given on the attached Process Mass Balance sheet

3) The physical state of most streams is shown (gas, g; liquid, l; solid, s)

4) The process numbering is as follows,

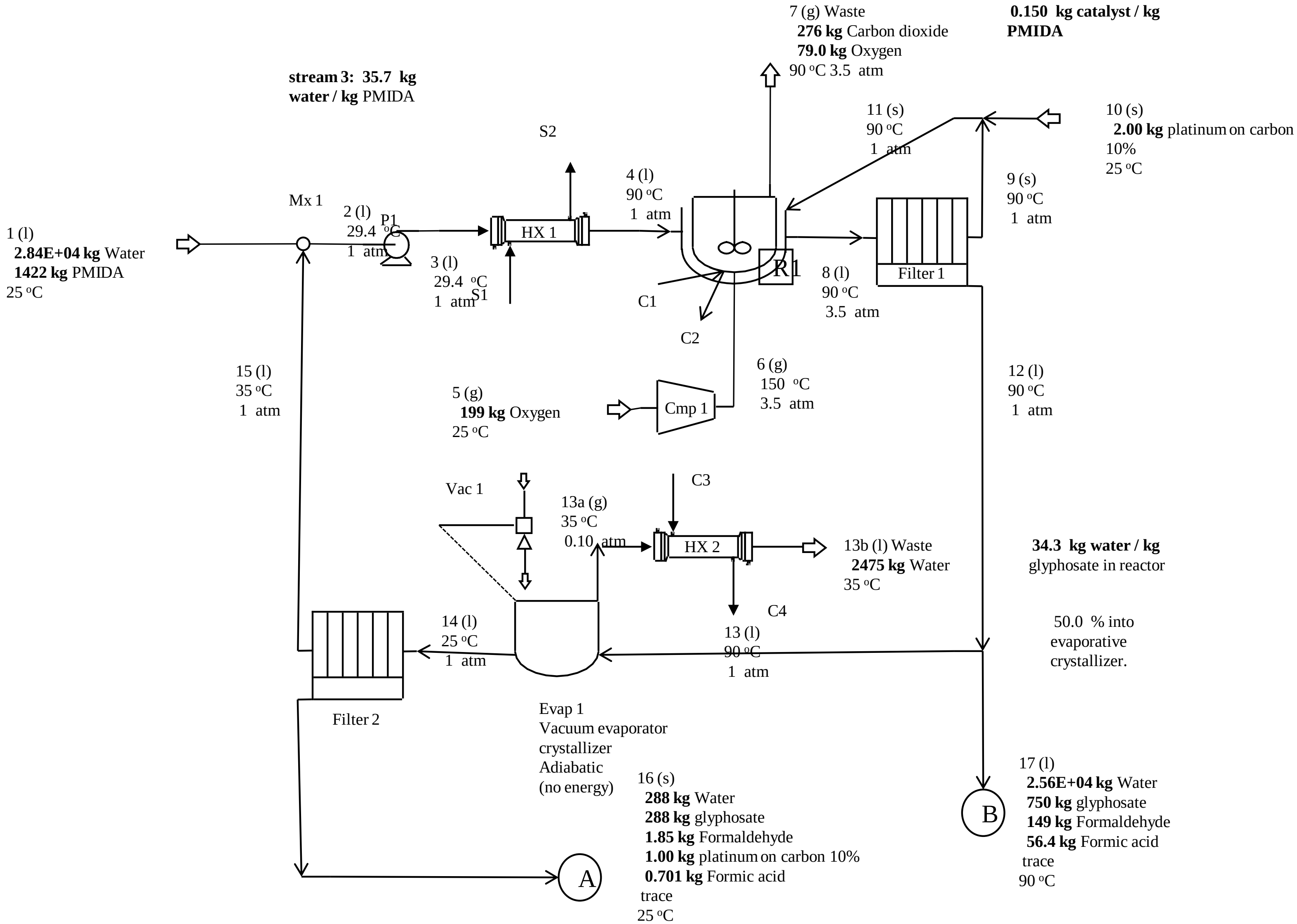
- generally numbers progress from the start to the end of the process
- numbers are used for process streams
- C i , i = 1,..n are used for all cooling non-contact streams
- S j, j = 1,...n are used for all steam heating non-contact streams

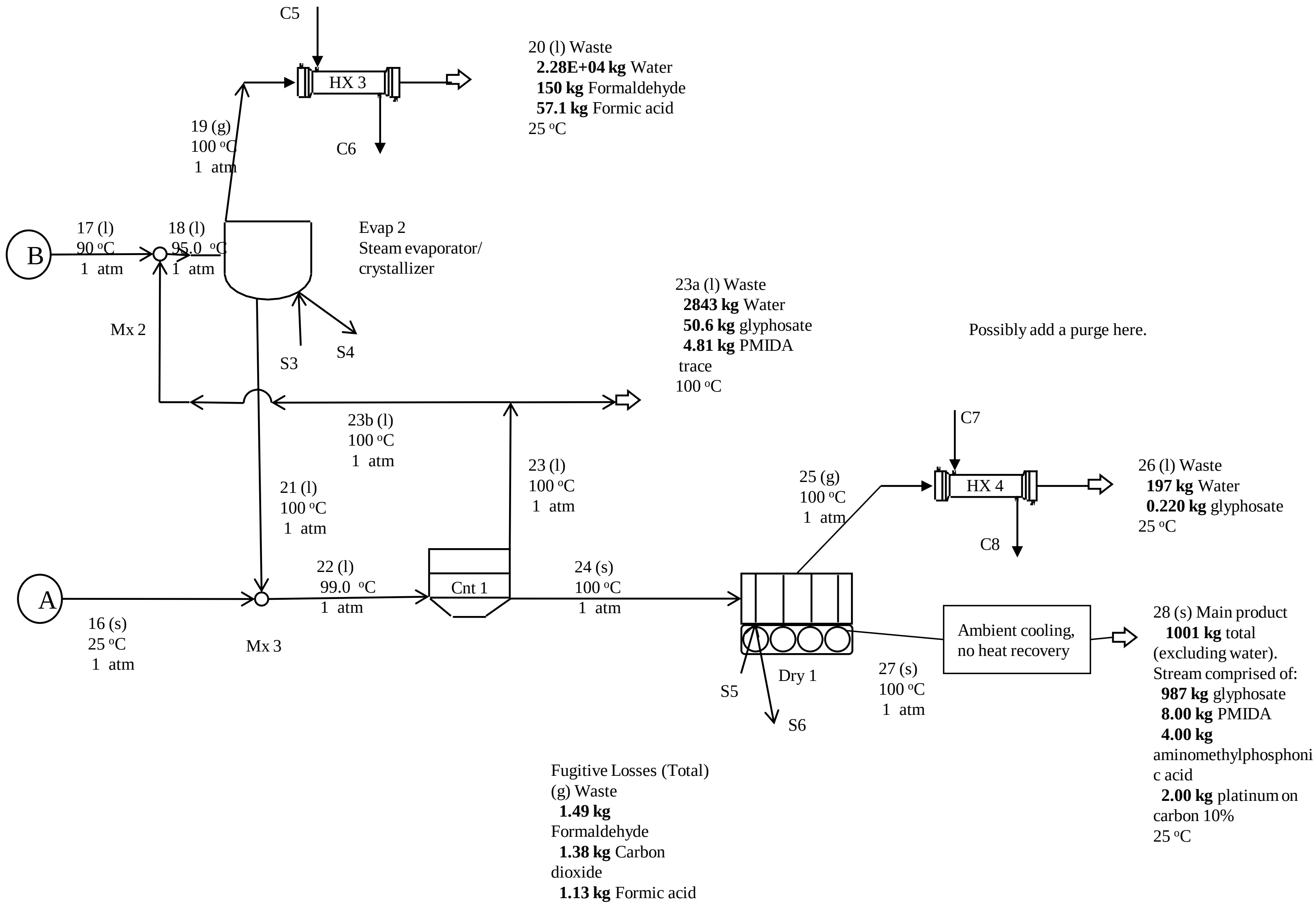
5) Recycle streams are shown with dotted lines

For most streams, the temperature and pressure are shown, if the pressures are greater than 1 atm

Process Diagram or Boundary of LCI

Steam enters the process as a gas at 207 ^{o}C and leaves as a liquid at 207 ^{o}C. Cooling water enters at 20 ^{o}C and leaves at 50 ^{o}C.
Unles




C5
HX 3
C6
20 (l) Waste
2.28E+04 kg Water
150 kg Formaldehyde
57.1 kg Formic acid
25 °C
19 (g)
100 °C
1 atm
B
17 (l)
90 °C
1 atm
18 (l)
95.0 °C
1 atm
Evap 2
Steam evaporator/
crystallizer
Mx 2
S3
S4
23a (l) Waste
2843 kg Water
50.6 kg glyphosate
4.81 kg PMIDA
trace
100 °C
Possibly add a purge here.
23b (l)
100 °C
1 atm
C7
HX 4
C8
21 (l)
100 °C
1 atm
23 (l)
100 °C
1 atm
25 (g)
100 °C
1 atm
26 (l) Waste
197 kg Water
0.220 kg glyphosate
25 °C
A
22 (l)
99.0 °C
1 atm
Cnt 1
24 (s)
100 °C
1 atm
16 (s)
25 °C
1 atm
Mx 3
Ambient cooling,
no heat recovery
28 (s) Main product
1001 kg total
(excluding water).
Stream comprised of:
987 kg glyphosate
8.00 kg PMIDA
4.00 kg
aminomethylphosphonic acid
2.00 kg platinum on
carbon 10%
25 °C
Dry 1
S5
S6
27 (s)
100 °C
1 atm
Fugitive Losses (Total)
(g) Waste
1.49 kg
Formaldehyde
1.38 kg Carbon
dioxide
1.13 kg Formic acid

Mass Balance of Chemicals in Each Process Stream

All flow rates are given in kg / hr.

Physical state of chemical losses: Gas, Liquid, Solid.

	Comments	Streams	Temp [C]	P	Phase	Total Flow	Water	PMIDA	Oxygen	aminomethylphosphonic acid	Formaldehyde	Formic acid	Carbon dioxide	glyphosate	platinum on carbon 10%
Input		1	25.0	1.00	l	2.98E+04	2.84E+04	1422							
		Stream 15:Recycle input				2.35E+04	2.28E+04	13.7	0	6.60	146	55.7		462	
		Stream 15:Recycle calculated				2.35E+04	2.28E+04	13.8	0	6.66	147	55.7	0	462	0
		Stream 15:Recycle residue				-0.274	0.194	-0.101	0	-0.0576	-0.292	0.0275	0	-0.0448	0
		2	29.4	1.00	l	5.33E+04	5.12E+04	1435	0	6.60	146	55.7	0	462	0
		3	29.4	1.00	l	5.33E+04	5.12E+04	1435	0	6.60	146	55.7	0	462	0
		4	90.0	1.00	l	5.33E+04	5.12E+04	1435	0	6.60	146	55.7	0	462	0
Input		5	25.0	1.00	g	199			199						
		6	150	3.50	g	199			199						
		Stream 11:Recycle input				428	213								215
		Stream 11:Recycle calculated				429	213	0	0	0	0	0	0	0	215
		Stream 11:Recycle residue				-0.321	-0.321	0	0	0	0	0	0	0	0
R1	1408	kg	PMIDA		:	is converted in rxn (98.1 % of reactor input)									
	37.2	kg	Formaldehyde		:	is converted in rxn (25.4 % of reactor input)									
	10.5	kg	glyphosate		:	is converted in rxn (2.27 % of reactor input)									
		Input to reactor			:	5.39E+04	5.14E+04	1435	199	6.60	146	55.7	0	462	215

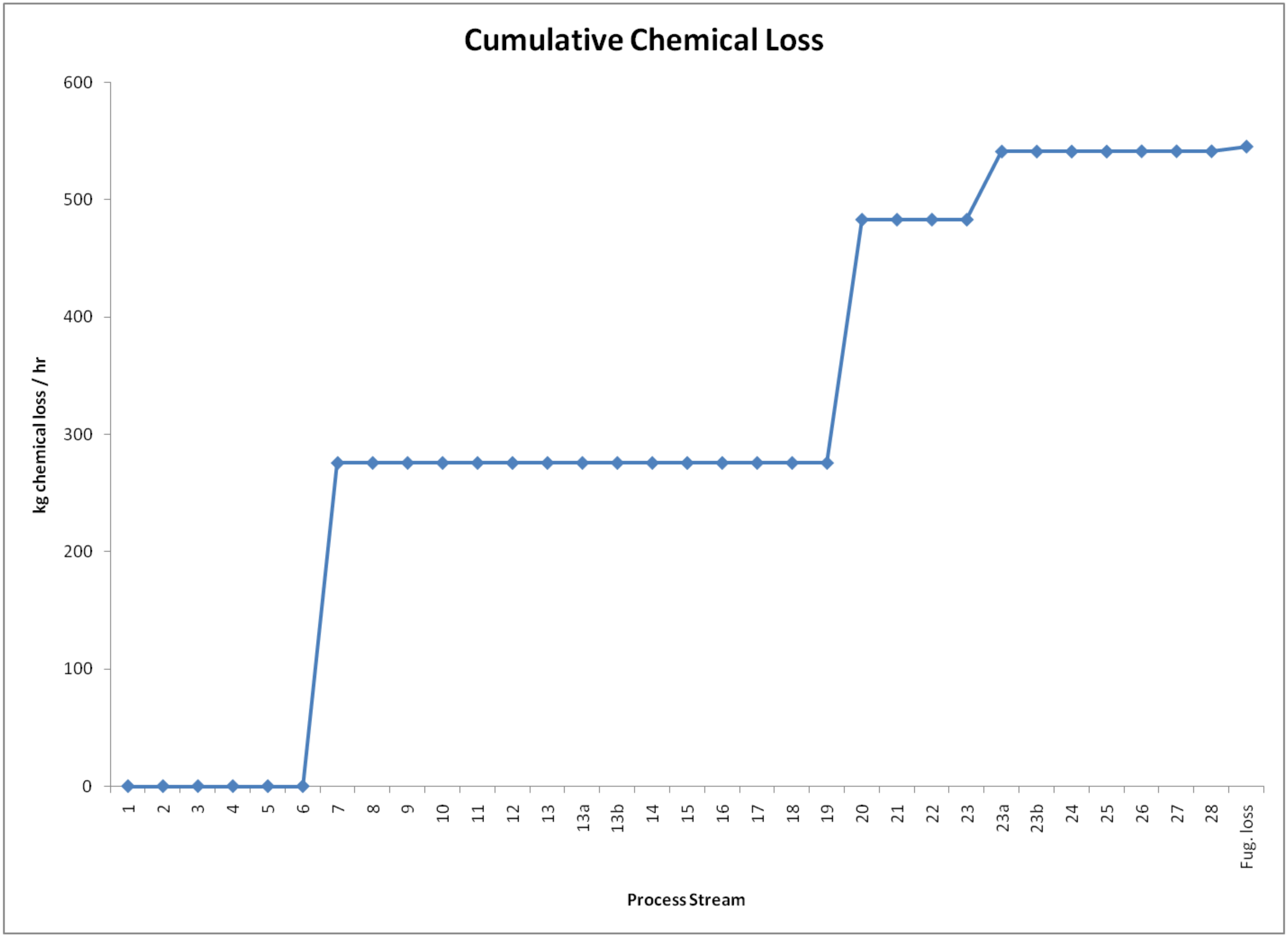
	Comments	Streams	Temp [C]	P	Phase	Total Flow	Water	PMIDA	Oxygen	aminomethylphosphonic acid	Formaldehyde	Formic acid	Carbon dioxide	glyphosate	platinum on carbon 10%
		R1 Reaction Coefficient 1			:			-1.00	-0.500		1.00		1.00	1.00	
		R1 Conversion 1 [kg/hr]			:	0		-1408	-99.2		186		273	1048	
		R1 Conversion 1 [kgmol/hr]			:	6.20		-6.20	-3.10		6.20		6.20	6.20	
		R1 Reaction Coefficient 2			:				-0.500		-1.00	1.00			
		R1 Conversion 2 [kg/hr]			:				-19.8		-37.2	57.0			
		R1 Conversion 2 [kgmol/hr]			:	1.24			-0.620		-1.24	1.24			
		R1 Reaction Coefficient 3			:				-0.500	1.00	1.00		1.00	-1.00	
		R1 Conversion 3 [kg/hr]			:	0			-0.992	6.88	1.86		2.73	-10.5	
		R1 Conversion 3 [kgmol/hr]			:				-0.0310	0.0620	0.0620		0.0620	-0.0620	
		Flow out of reactor			:	5.39E+04	5.14E+04	27.9	79.0	13.5	297	113	276	1500	215
		Primary product			:	glyphosate									
		Total conversion			:		0	99.0	60.3	NA	NA	NA	NA	NA	0
		Per pass conversion			:		0	98.1	60.3	NA	NA	NA	NA	NA	0
		Total yield from reactor			:			99.0	81.8		NA		NA	NA	
Waste		7	90.0	3.50	g	-355			-79.0				-276		
		8	90.0	3.50	l	5.36E+04	5.14E+04	27.9	0	13.5	297	113	0	1500	215
		9	90.0	1.00	s	427	213								213
Input		10	25.0	1.00	s	2.00									2.00
		11	90.0	1.00	s	429	213	0	0	0	0	0	0	0	215
		12	90.0	1.00	l	5.31E+04	5.12E+04	27.9	0	13.5	297	113	0	1500	2.00
	0.500	13	90.0	1.00	l	2.66E+04	2.56E+04	13.9	0	6.74	149	56.4	0	750	1.00
Waste		13a	35.0	0.100	g	-2475	-2475								
		13b	35.0	1.00	l	2475	2475								
		14	25.0	1.00	l	2.41E+04	2.31E+04	13.9	0	6.74	149	56.4	0	750	1.00
		15	35.0	1.00	l	2.35E+04	2.28E+04	13.8	0	6.66	147	55.7	0	462	0
Display in PFD		16	25.0	1.00	s	579	288	0.173	0	0.0839	1.85	0.701	0	288	1.00
Display in PFD		17	90.0	1.00	l	2.66E+04	2.56E+04	13.9	0	6.74	149	56.4	0	750	1.00
		Stream 23b:Recycle input				2.61E+04	2.56E+04	42.0	0	22.2	1.00	1.00	0	455	0

	Comments	Streams	Temp [C]	P	Phase	Total Flow	Water	PMIDA	Oxygen	aminomethylphosphonic acid	Formaldehyde	Formic acid	Carbon dioxide	glyphosate	platinum on carbon 10%
	1001	Stream 23b:Recycle calculated				2.61E+04	2.56E+04	43.3	0	22.5	0.900	0.900	0	455	0
		Stream 23b:Recycle residue				-0.0901	1.29	-1.31	0	-0.323	0.100	0.1000	0	0.0500	0
		18	95.0	1.00	l	5.27E+04	5.12E+04	55.9	0	28.9	150	57.4	0	1205	1.00
		19	100	1.00	g	2.30E+04	2.28E+04				150	57.1	0		
Waste		20	25.0	1.00	l	-2.30E+04	-2.28E+04	0	0	0	-150	-57.1	0	0	0
		21	100	1.00	l	2.96E+04	2.83E+04	55.9	0	28.9	-0.848	0.299	0	1205	1.00
		22	99.0	1.00	l	3.02E+04	2.86E+04	56.1	0	29.0	1.000	1.00	0	1492	2.00
		23	100	1.00	l	2.90E+04	2.84E+04	48.1	0	25.0	1.000	1.00	0	506	0
Waste	0.100	23a	100	1.00	l	-2902	-2843	-4.81	0	-2.50	-0.1000	-0.100	0	-50.6	0
		23b	100	1.00	l	2.61E+04	2.56E+04	43.3	0	22.5	0.900	0.900	0	455	0
		24	100	1.00	s	1198	197	8.00		4.00				987	2.00
		25	100	1.00	g	198	197	0	0	0	0	0	0	0.220	0
Waste		26	25.0	1.00	l	-198	-197							-0.220	
		27	100	1.00	s	1001	0	8.00	0	4.00	0	0	0	987	2.00
Main product		28	25.0	1.00	s	-1001	0	-8.00	0	-4.00	0	0	0	-987	-2.00
		Product purity (%)			:	98.6									
		Main product			:	glyphosate									
		Overall Rxn coefficients			:			-1.00	-0.500		1.00		1.00	1.00	
		Total yield of process (from reactant)			:			93.2	46.9		NA		NA	NA	
Waste		Fugitive Losses (Total)			g	-3.99	0	0	0	0	-1.49	-1.13	-1.38	0	0
		Input Sum			:	3.00E+04	2.84E+04	1422	199	0	0	0	0	0	2.00
		Fugitive Replacement of Reactants			:	0		0	0						
		Total Input (Input + Fugitive Replacement)			:	3.00E+04	2.84E+04	1422	199	0	0	0	0	0	2.00
		Product Sum			:	1001	0	8.00	0	4.00	0	0	0	987	2.00
		Main product flow			:	1001	0	8.00	0	4.00	0	0	0	987	2.00

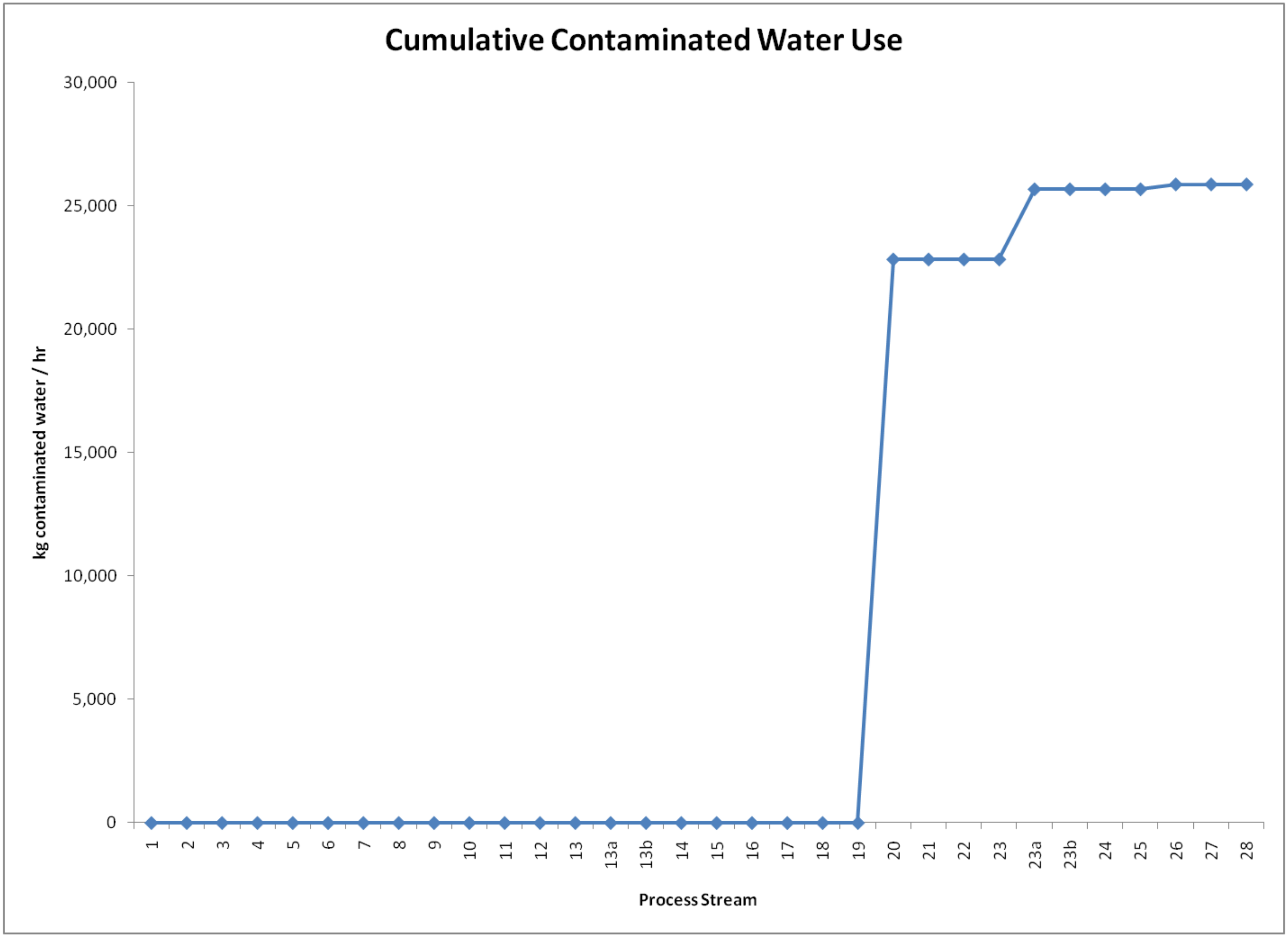
	Comments	Streams	Temp [C]	P	Phase	Total Flow	Water	PMIDA	Oxygen	aminomethylphosphonic acid	Formaldehyde	Formic acid	Carbon dioxide	glyphosate	platinum on carbon 10%
		Net Input (in - out, omitting fugitives)			:	0.905									

Type	Label	Temp, C	P, atm	Phase	Total flow	Steam	Water
Input	C1	20.0	1.00	l	5615		5615
Cooling out	C2	50.0	1.00	l	-5615		-5615
Input	C3	20.0	1.00	l	4.04E+04		4.04E+04
Cooling out	C4	50.0	1.00	l	-4.04E+04		-4.04E+04
Input	C5	20.0	1.00	l	4.88E+04		4.88E+04
Cooling out	C6	50.0	1.00	l	-4.88E+04		-4.88E+04
Input	C7	20.0	1.00	l	406		406
Cooling out	C8	50.0	1.00	l	-406		-406
Input	S1	207	1.00	l	8100	8100	
Steam out	S2	207	1.00	l	-8100	-8100	
Input	S3	207	1.00	l	3.20E+04	3.20E+04	
Steam out	S4	207	1.00	l	-3.20E+04	-3.20E+04	
Input	S5	207	1.00	l	261	261	
Steam out	S6	207	1.00	l	-261	-261	

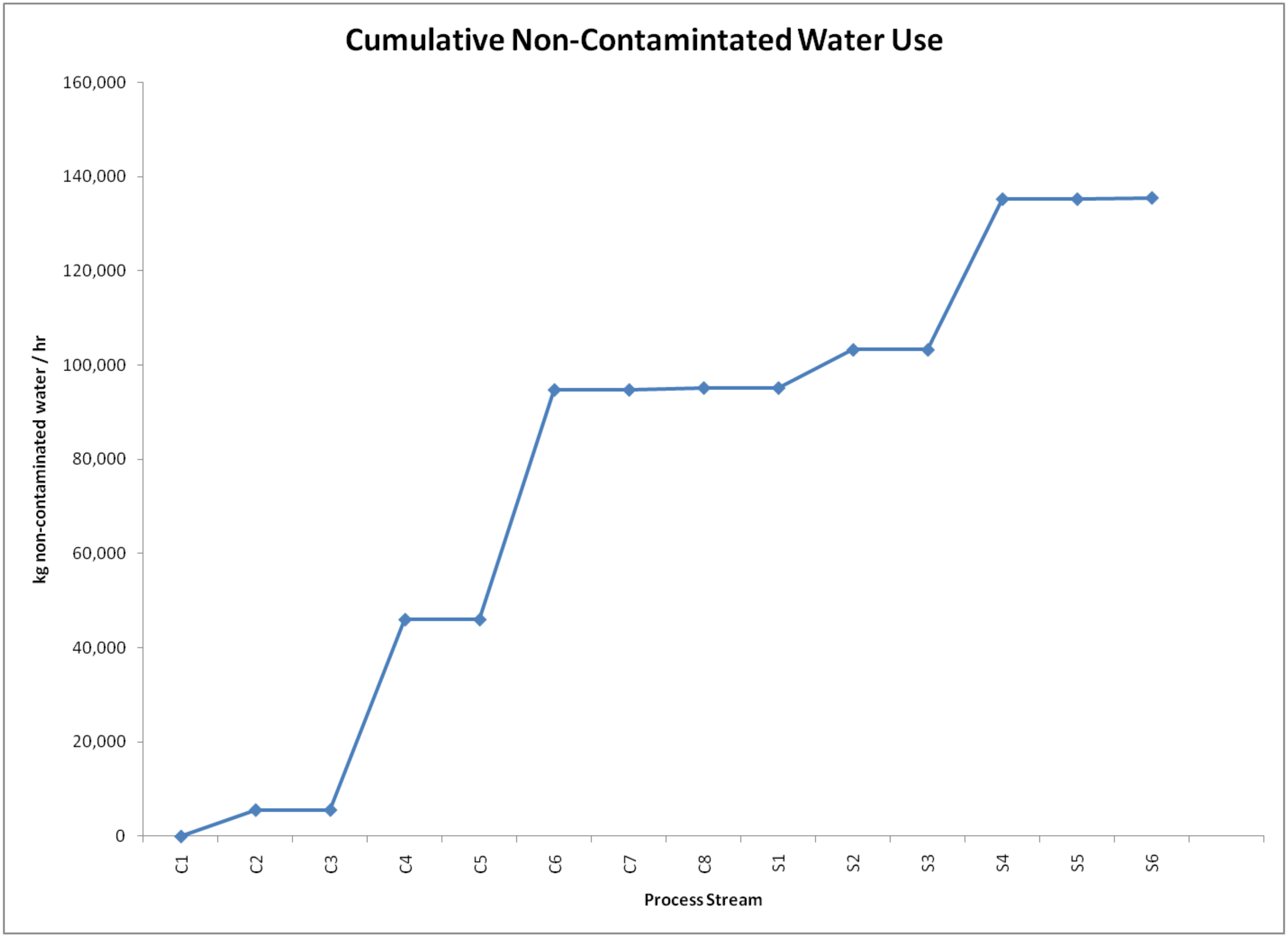
Graph of Cumulative Chemical Losses through Manufacturing Process



Graph of Cumulative Contaminated Water Use / Emission through Manufacturing Process



Graph of Cumulative Non-Contaminated Water Use / Emission through Manufacturing Process



Energy Input for each Unit Process, Cumulative Energy Requirements, Cooling Requirements (exotherms), and Assumed Heat Recovery from Hot Streams Receiving Cooling

Energy Input [MJ / hr]						Cooling Requirements [MJ / hr]							
Process Diagram Label	Unit	Energy input [MJ / 1000 kg Product]	Cumulative energy [MJ / 1000 kg Product]	To [C] (Used to determine energy type)	Energy Type	Process diagram label	Unit	Energy Loss	Cumulative cooling water energy	Tef [C] (for recovery efficiency)	Recovery Efficiency	Energy Recovered	Cumulative recovered [MJ / 1000 kg Product]
P1	Pump 1	3.76	3.76		E	R1	Reactor 1	-824	-824	90.0	0.250	-206	-206
Hx1	Heat exchanger 1	1.32E+04	1.32E+04	90.0	S	Hx2	Heat exchanger 2	-5969	-6793	35.0	0	0	-206
Cmp1	Compressor 1	30.8	1.32E+04		E	Hx3	Heat exchanger 3	-5.80E+04	-6.48E+04	100	0.250	-1.45E+04	-1.47E+04
MxE1	Mixer electricity 1	236	1.34E+04		E	Hx4	Heat exchanger 4	-501	-6.53E+04	100	0.250	-125	-1.48E+04
Vac1	Vacuum electricity 1	27.2	1.35E+04		E								
Evp2	Evaporator 2	5.20E+04	6.55E+04	100	S								
Cnt1	Centrifuge 1	202	6.57E+04		E								
Dry1	Dryer 1	439	6.61E+04	100	S								
	Potential recovery	-1.48E+04	5.13E+04										
	Net energy		5.13E+04				Potential recovery:						-1.48E+04
	Electricity	500	E	[MJ/hr]									
	DowTherm	0	D	[MJ/hr]									
	Heating steam	6.56E+04	S	[MJ/hr]		Evap 1, adiabatic:	Evap 1 is adiabatic, and energy should be near zero						
	Direct fuel use	0	F	[MJ/hr]									
	Heating natural gas	0	G	[MJ/hr]									
	Diesel process	0	Ds	[MJ/hr]									
	Undefined	0	U	[MJ/hr]									
	Heating coal	0	C	[MJ/hr]									
	Energy input	6.61E+04		[MJ/hr]									

	requirement												
	Cooling water	- 6.53E+04		[MJ/hr]									
	Cooling refrigeration			[MJ/hr]									
	Potential heat recovery	- 1.48E+04		[MJ/hr]									
	Net energy	5.13E+04		[MJ/hr]									

Graph of Cumulative Energy Requirements