

Environmental Profile of the Antibiotic Vancomycin

Vancomycin HCl is an effective treatment of serious infections caused by susceptible organisms resistant to penicillins (*methicillin-resistant S. aureus*, MRSA) and multidrug-resistant *S. epidermidis* (MRSE) or in individuals with serious allergy to penicillins. This antibiotic is made from basic natural and synthetic chemicals and hence there is an environmental profile of the industrial manufacturing process as well as the extensive supply chains. Environmental Clarity have evaluated this environmental profile using the methodologies, database, and analysis procedures of the Environmental Genome (www.environmentalgenome.org). We have also applied these techniques to other drugs with more complex supply chains, such as Paroxetine (Paxil), Sertraline (Zoloft), and Ephedrine. Our database of materials is expanding to include a large number of excipients as well (19). This information is critical for the requests by customers and investors for carbon footprint and Scope 3 requirements (the environmental part of ESG). Thus, the path forward for corporations addressing other important pharmaceutical products is clear and now available.

The supply chains for vancomycin are extensive, Figure 1. These are tracked from product on the left back to the original natural resources in the earth, the salmon colored cells toward the right. The primary biological inputs for vancomycin synthesis are dextrose and soy flour, while the primary synthetic chemicals are isopropanol, ammonia, ammonium chloride, and urea.

The environmental profile has been evaluated for a number of parameters, but three principal ones are listed here:

Natural resource energy (NRE) is the measure of the total energy value of all extracted fossil fuel materials used as manufacturing and transport energy plus the fossil content needed for the product mass, expressed as MJ NRE/kg product or per product. This metric is used as an indicator of fossil circularity.

Global warming potential (GWP) from TRACI 2.1 (US EPA, 2013), expressed as kg CO_{2equivalent}/kg product or per product.

Blue water is the total of all water evaporated during production or physically incorporated into the product¹. Thus, blue water does not include non-contaminated water returned to the environment (i.e. from steam heating or cooling water systems) or contaminated water (i.e. from chemical manufacturing) that is returned to the environment via a wastewater treatment process, expressed as kg bluewater/kg product or per product.

Metric	
Natural Resource Energy	795 MJ HHV/ kg Vancomycin HCl
Global Warming Potential	63 GWP emissions, kg CO2e / kg Vancomycin HCl
Bluewater	96 kg bluewater/kg Vancomycin HCl

¹ Aviso, K., Tan R., Culaba A. and J. Cruz (2011), Fuzzy input-output model for optimizing eco-industrial supply chains under water footprints constraints, J Cleaner Production, 19:187-196.

Cradle to gate chemical tree for Van										
	Natural	Linellageted	Allanatad							
Key Level 1	resources Level 2	Unallocated Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10	Level 11 Level 12
Vancomycin HCl	Ammonia	Natural gas	blue water	7		•	•	•	•	•
1,000	1,000	206	Natural gas							
			(unprocessed)	10						
		nitrogen from	2							
		air 385	Air (untreated)	35						
		oxygen from		~						
		air 171	Air (untreated)	71						
		Water for rxn	Water (untreated)							
	Ammonium	267	26	57						
	chloride	Ammonia	Natural gas	blue water						
	1,132	182	37	.5 12 Natural gas	2.1					
				(unprocessed)	22					
			nitrogen from air	Air (untreated)						
			69		9.9					
			oxygen from air 31	Air (untreated)	1.0					
			Water for rxn 48	Water (untreated)	3.5					
		Carbon		-	<i></i>					
		dioxide 470	Natural gas 96	blue water	1.3					
]	Natural gas						
				(unprocessed) 96	3.8					
			nitrogen from air	Air (untreated)						
			oxygen from air	Air (untreated)	81					
			80	.2 80	0.2					
			Water for rxn	Water (untreated)	25					
		Sodium			_					
		chloride 629	salt rock, in ground 80	02						
		Water for rxn 97.0	Water (untreated) 97	.0						
		07.0	01		Potassium		sylvinite ore (in	1		
	Dextrose 12,099	corn starch 11,639	Corn 13,73	K in Fertilizer	chloride 3.7 15	Sylvinite ore 8 46	ground) 4 464			
	12,000	11,000	10,71	N in fertilizer	Ammonia	Natural gas	blue water	1		
				2	54 16 3	5 34.	0 11.0 Natural gas	2		
							(unprocessed)			
						nitrogen from air	34.7 Air (untreated)	A		
						63.	5 63.5	5		
						oxygen from air 28.	Air (untreated) 28.2	>		
						Water for rxn	Water (untreated)			
						diammonium phosphat		,		1
					N in DAP 25.3	(DAP)	Ammonia	Natural gas	blue water 0.97	E
					25	30.	9 14.0	3.0	Natural gas	3
									(unprocessed) 3.0	7
								nitrogen from air	Air (untreated)	1
								5.62 oxygen from air	2 5.6 Air (untreated)	2
								2.50	2.5	0
								Water for rxn 3.90	Water (untreated) 3.9	0
									phosphate ore, in	1
							Phosphoric acid 42.0	Phosphate rock 91.2	ground 31	8
										oxygen Air
					1			Sulfuric acid 78.1	Sulfur trioxide 63.	from air (untreated) 4 39.4 39.
										oil (in
										Sulfur ground) 27.4 28.
										Water
										Water for rxn (untreated) 2.39 2.3
									Water for rxn	Water (untreated)
									15.	
					1			Water for rxn 24.7	Water (untreated) 24.	7
					Urea	Ammonia	Natural gas	blue water		-
					200		5 23.7	7.66	5	
					1			Natural gas (unprocessed)		
					1		nitrogen from al-	24.1	1	
							nitrogen from air 44.2	Air (untreated) 44.2	2	
					-1				1	
							oxygen from air	Air (untreated)		
							19.6 Water for rxn	19.6	5	
						Carbon dioxide	19.6	19.6 Water (untreated)	1	

	1										
									Natural gas (unprocessed)		
									31.2		
								nitrogen from air 57.1	Air (untreated) 57.1		
								oxygen from air 25.3	Air (untreated) 25.3		
								Water for rxn	Water (untreated)		
				╌			diammonium phosphate	39.6	39.6		ī
				Р	in fertilizer	P in DAP	(DAP)	Ammonia	Natural gas	blue water	
					50	3 50 .:	114	29.2	6.02	1.95 Natural gas	
										(unprocessed)	
				+					nitrogen from air	6.14 Air (untreated)	
									11.2	11.2	
									oxygen from air 4.99	Air (untreated) 4.99	
				-					Water for rxn 7.79	Water (untreated) 7.79	
				+					7.19	phosphate ore, in	
				-				Phosphoric acid 84.1	Phosphate rock 182	ground 636	
								04.1	102		oxygen Air
									Sulfuric acid 156	Sulfur trioxide 127	from air (untreated) 78.8 78.8
											oil (in
				+							Sulfur ground) 54.7 56.3
											Water
											Water for rxn (untreated) 4.78 4.78
										Meter	Water
										Water for rxn 31.7	(untreated) 31.7
									Water for rxn	Water (untreated)	
		Hydrogen		S	odium chloride in brine	salt rock, in			49.3	49.3	1
		chloride 19.4	Chlorine		6 wtpct	ground	3				
		19.4	·	-		Water	1				
				V	Vater for rxn 3.3	(untreated) 3.30					
			Ethylene	N	laphtha	blue water	1				
			5.	5.50	5.6	1 15.					
						oil (in ground)					
		Sodium	sodium chloride in brin	ne		5.6					
		hydroxide	26 wtpct	Si	alt rock, in ground						
		21.2	Water for rxn	17.1 V	Vater (untreated)	1					
			5.	5.00	5.0	0					
	isopropanol 100	Propylene 92.0	Naphtha 90	93.8	lue water 20	3					
				oi	il (in ground) 95						
				+	90	0	1				
		Sulfuric acid 35.9	Sulfur trioxide	29.1	xygen from air 18	Air (untreated					
		55.5				10.	Ť				
				S	Sulfur 12	oil (in ground) 6 12.9					
				上		Water	1				
				V	Vater for rxn 1.	(untreated) 0 1.10	,				
			Water for rxn	v.	Vater (untreated)		•				
		Water for rxn	Water (untreated)	7.29	7.2	8					
		31.2		31.2							
	Soy Flour	soybean meal	n-hexane	N	laphtha	blue water	l				
	4,625		4	18.5	48		6				
						oil (in ground)					
						49.1 Potassium		sylvinite ore (in	ı		
			Soybean		(in Fertilizer	chloride	Sylvinite ore	ground)			
			5,8	842 N	12 I in fertilizer	7 25 Ammonia	Natural gas	748 blue water			
				IN .	65			2.84			
								Natural gas (unprocessed)			
								8.95			
				\perp			nitrogen from air 16.4	Air (untreated) 16.4			
							oxygen from air	Air (untreated)			
							7.27 Water for rxn	7.27 Water (untreated)			
							11.4	11.4			,
						N in DAP	diammonium phosphate (DAP)	Ammonia	Natural gas	blue water	
						6.4	14.7	3.77	0.776	0.251	
										Natural gas (unprocessed)	
										0.792	
									1.45	Air (untreated) 1.45	
									oxygen from air	Air (untreated)	Ī
									0.643 Water for rxn	0.643 Water (untreated)	†
				1		1		1	1.00		

Phosphoric acid Phosph	phosphate ore, in ground
10.8	23.5 81.9
Sulfurio	oxygen Air acid Sulfur trioxide from air (untreated)
	20.1 16.4 10.2 10.2
	oil (in Sulfur ground)
	7.05 7.26
	Water Water for rxn (untreated)
	0.616 0.616
	Water Water for rxn (untreated)
	4.09
VNater for	or rxn Water (untreated) 6.36
Urea Ammonia Natural gas blue wat	ter
52.3 29.6 6.10	1.97
Natural g (unproce	
	6.22
nitrogen from air 11.4	11.4
oxygen from air or	
5.05 Water for non Water (1997)	5.05 untreated)
7.89	7.89
Carbon dioxide Natural gas blue wet 38.2 7.88	2.55
Natural	gas
(unproce	essed) 8.04
nitrogen from air Air (untro	reated)
14.7 oxygen from air Air (untr	14.7
6.53	6.53
Water for non Water (u	untreated) 10.2
diammonium phosphate	10.2
P in fertilizer P in DAP (DAP) Ammonia Natural 221 221 499 128	gas blue water 8.54
22.1 22.1 459 120	Natural gas
	(unprocessed)
nitroger	26.9 n from air Air (untreated)
	49.3
oxygen	from air Air (untreated) 21.9 21.9
Water fo	or rxn Water (untreated)
	34.2 34.2 phosphate ore, in
	ate rock ground
369	799 2,786 oxygen Air
Sulturio	acid Sulfur trioxide from air (untreated)
	685 556 345 345 oil (in
	Sulfur ground)
	240 247 Water
	Water for rxn (untreated)
	20.9 Vater
	Water for rxn (untreated)
Water fo	139 139 139 or rxn Water (untreated)
	vater (untreated) 216 216
Urea Ammonia Natural gas blue water 1,200 679 140 45.3	
1,200 679 140 45.3 Natural gas	
(unprocessed)	
nitrogen from air Air (untreated)	
261 261	
oxygen from air Air (untreated) 116 116	
Water for rxn Water (untreated)	
181 181 Carbon	
dioxide Natural gas blue water	
878 181 58.5 Natural gas	
(unprocessed)	
nitrogen from air Air (untreated)	
338 338	
oxygen from air Air (untreated)	
Water for rxn Water (untreated) 234	

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