

## 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](http://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<sub>2equivalent</sub>/kg product or per product.

**Blue water** is the total of all water evaporated during production or physically incorporated into the product<sup>1</sup>. 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 CO <sub>2e</sub> / kg Vancomycin HCl
Bluewater	96 kg bluewater/kg Vancomycin HCl

<sup>1</sup> 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 Vancomycin HCl																			
Key	Natural resources	Unallocated	Allocated																
Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10	Level 11	Level 12								
Vancomycin HCl	1,000 Ammonia	1,000 Natural gas	206 blue water	66.7															
				Natural gas (unprocessed)	210														
				nitrogen from air	385	Air (untreated)	385												
				oxygen from air	171	Air (untreated)	171												
			Water for rxn	267	Water (untreated)	267													
		1,132 Ammonium chloride	182 Ammonia	37.5 Natural gas	blue water	12.1													
					Natural gas (unprocessed)	38.2													
				nitrogen from air	69.9	Air (untreated)	69.9												
				oxygen from air	31.0	Air (untreated)	31.0												
				Water for rxn	48.5	Water (untreated)	48.5												
	470 Carbon dioxide		96.8 Natural gas	blue water	31.3														
				Natural gas (unprocessed)	98.8														
				nitrogen from air	181	Air (untreated)	181												
				oxygen from air	80.2	Air (untreated)	80.2												
				Water for rxn	125	Water (untreated)	125												
			629 Sodium chloride	802 salt rock, in ground															
		97.0 Water for rxn	97.0 Water (untreated)																
	12,099 Dextrose	11,639 corn starch	13,735 Corn	K in Fertilizer	78.7	Potassium chloride	158	Sylvinite ore	464	464									
				N in fertilizer	254	Ammonia	165	Natural gas	34.0	blue water	11.0								
								Natural gas (unprocessed)	34.7										
								nitrogen from air	63.5	Air (untreated)	63.5								
								oxygen from air	28.2	Air (untreated)	28.2								
								Water for rxn	44.0	Water (untreated)	44.0								
								N in DAP	25.2	diammonium phosphate (DAP)	56.9	Ammonia	14.6	Natural gas	3.01	blue water	0.975		
														Natural gas (unprocessed)	3.07				
														nitrogen from air	5.62	Air (untreated)	5.62		
														oxygen from air	2.50	Air (untreated)	2.50		
												Water for rxn	3.90	Water (untreated)	3.90				
												Phosphoric acid	42.0	Phosphate rock	91.2	318			
												Sulfuric acid	78.1	Sulfur trioxide	63.4	oxygen from air	39.4	Air (untreated)	39.4
														Sulfur	27.4	oil (in ground)	28.2		
														Water for rxn	2.39	Water (untreated)	2.39		
														Water for rxn	15.9	Water (untreated)	15.9		
														Water for rxn	24.7	Water (untreated)	24.7		
		203 Urea	115 Ammonia	23.7 Natural gas	blue water	7.66													
					Natural gas (unprocessed)	24.1													
					nitrogen from air	44.2	Air (untreated)	44.2											
	oxygen from air				19.6	Air (untreated)	19.6												
					30.6 Water for rxn	30.6 Water (untreated)													
			148 Carbon dioxide	30.6 Natural gas	blue water	9.88													



