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October 1989

ENVIRONMENT IMPACT ANALYSIS OF THE MANUFACTURE OF BENOMYL

1. INFORMATION SOURCES

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Process I: commercial scale manufacturer.

Process II: pilot plant level R&D of the same manufacturer.

- 2. PROCESS INFORMATION
 - 2.1 Schematic illustration of the syntheses

<u>3209N</u>

2.2 Definition of educts, intermediates and products

The chemical formulae and molecular weights of compounds used in the synthesis of Benomyl are listed in appendix 1.

2.3 Chemical reactions

(a) $2CaNCN + 2H_2O + 2C1COOCH_3 = 2NCNHCOOCH_3 + CaCl_2 + Ca(OH)_2$ 160.22 + 36.03 + 189.00 200.16 110.99 74.10

(b) NCNHCOOCH₃ + C₆H₄(NH₂)₂ + HCl = C₉H₉N₃O₂ + NH₄Cl

100.08 108.14 36.46 191.19 53.49

(c) $C_{9}H_{9}N_{3}O_{2} + H_{3}C(CH_{2})_{3}NCO = C_{14}H_{18}N_{4}O_{3}$

191.19 99.13 290.32

(d) $HCOOC_2H_5 + H_3C(CH_2)_3NH_2 = H_3C(CH_2)_3NHCHO + C_2H_5OH$

74.08 73.14 101.15 46.07

(e) $H_3C(CH_2)_3NHCHO + SO_2Cl_2 = H_3C(CH_2)_3NHCClO + SO_2 + HCl$

101.15 134.98 135.59 64.07 36.46

(f) $2C_{9}H_{9}N_{3}O_{2} + 2H_{3}C(CH_{2})_{3}$ MHCC10 + CaCO₃ = $2C_{14}H_{18}N_{4}O_{3} + CaCl_{2} + H_{2}O + CO_{2}$ 382.38 271.18 100.09 580.64 110.99 18.02 44.01

Combined equation of the synthesis

(g) Process I

 $2CaNCN + 2C1COOCH_3 + 2H_2O + 2HC1 + 2C_6H_4(NH_2)_2 + 2H_3C(CH_2)_3NCO =$

 160.22
 189.00
 36.03
 72.92
 216.28
 198.26

 $= 2C_{14}H_{18}N_{4}O_{3} + CaCl_{2} + Ca(OH)_{2} + 2NH_{4}Cl$

580.64 110.99 74.10 106.98

(h) Process II

 $2CaNCN + 2C1COOCH_3 + 2H_2O + 2HC1 + 2C_6H_4(NH_2)_2 + HCOOC_2H_5 +$

160.22 189.00 36.03 72.92 216.28 148.16

+ $H_3C(CH_2)_3NH_2$ + $2SO_2Cl_2$ + $CaCC_3$ = $2C_{14}H_{18}N_4O_3$ + $2CaCl_2$ + $Ca(OH)_2$ + 146.28 269.96 100.09 580.64 221.98 74.10

+ $2NH_4C1$ + $2C_2H_5OH$ + $2SO_2$ + 2HC1 + H_2O + CO_2

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106.98 92.14 128.14 72.92 18.02 44.01

2.4 Other reactions used in the analysis

(i) $SO_2 + 2NaOH = Na_2SO_3 + H_2O$

64.07 80.00 126.06 18.02

(j) $SO_2Cl_2 + 4NaOH = 2NaCl + Na_2SO_4 + 2H_2O$

134.96 150.00 116.88 142.06 36.02

(k) $HC1 + NaOH = NaC1 + H_2O$

36.46 40.00 58.44 18.02

- (1) $N=C-NH-COOCH_3 + 3H_2O + 2HC1 = 2NH_4C1 + 2CO_2 + CH_3OH$
 - 100.08 54.05 72.92 106.98 88.02 32.04
 - 2.5 <u>Chemical conversion coefficients</u>

The molar chemical input conversion factors, F, and the material input coefficients, f, are given in table 1.

Material input	F	f1	f 2
Calcium cyanamide	276	628	644
Methylchlorocarbonate	326	454	465
o-Phenylenediamine	372	407	417
Carbendazim	659	686	705
Butylisocyanate	341	355	-
Ethyl formate	255	-	393
Butylamine	252	-	353
Butylformamide	348	-	483
Sulfuryl chloride	465	-	760
Butylcarbamyl chloride	467	-	644
Calcium carbonate	172	-	185

Table 1. Material requirements for benomyl synthesis (quantity/1000 kg of output)

Table 2. Yields in benomyl synthesis (percentage)

Material input	Process I	Process I
Calcium cyanamide	43.9	42.9
Methylchlorocarbonate	71.8	70.1
o-Phenylenediamine	91.6	89.2
Butylisocvanate	96.1	-
Butylamine	-	71.4
Ethyl formate	-	64.9
Sulfuryl chloride	-	61.2
Butylformamide	-	72.0
Butylcarbanyl chloride	-	72.5
Carbendazim	96.1	93.5

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1.6 Brief description of processes

Calcium cyanamide is dispersed in water and reacted with methyl chlorocarbonate at a temperature of 40 to 45°C. The mixture is filtered, o-phenylenediamine is added to the filtrate, the temperature is elevated to 90°C and the pH is adjusted between 4.0 and 4.5 to facilitate the formation of the benzimidazole ring.

The reaction mixture is cooled, solids are allowed to settle down, the supernatant liquid is pumped off and acetone is added to the aqueous suspension. Carbendazim is reacted either with butylisocyanate or with butylcarbamyl chloride at a temperature of about 20°C to yield benomyl. The mixture is cooled down to 0°C, benomyl is separated by filtration and dried.

Butylcarbamyl chloride is produced in two steps at room temperature. In step 1, the by-product ethanol is distilled off in vacuum. Hydrogen chloride and sulfur dioxide gases are by-produced in step 2 which are scrubbed in water and an aqueous alkali solution, respectively. Hydrochloric acid can be used in carbendazim synthesis whereas sodium sulfite solution can be sold for other industrial purposes.

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3. ENVIRONMENT IMPACT ASSESSMENT

Round 2,500 kg of materials are used for the production of 1,000 kg of benomyl using o-phenylenediamine as the feedstock (process I). The same figure is 4,020 kg, if the intermediate butylcarbamoyl chloride is synthetized from butylamine.

3.1 Material flow and informative material balance

A flow diagram is illustrated and related material balance calculations are summarized in appendices 2 and 3, respectively.

3.2 Material requirements

3.2.1 <u>Material consumption by nature of inputs</u>

Reactants	Process	<u>I</u>	Process I	I		
Calcium cyanamide	628 kg		644 kg			
Methylchlorocarbonate	454 kg		465 kg			
o-Phenylenediamine	407 kg		417 kg			
Butylisocyanate	355 kg		0			
Butylamine	-		353 kg			
Ethyl formate			393 kg			
Sulfuryl chloride			760 kg			
	1,844 kg	73.9 %	3,032 kg	75.5 %		
Reaction promoters						
Hydrochloric acid	213 kg		219 kg			
Calcium carbonate			185 kg			
	213 kg	8.5%	404 kg	10.1%		
Solvents						
Acetone	440 kg	17.6%	415 kg	11.2%		
Auxiliary materials						
Sodium hydroxide	<u></u>		129_kg	3.2%		
Total	2,497 kg	100.0%	4,016 kg	100.0%		

Reactants account for about three quarters of total material consumption. The shares of reaction promoters and solvents are about 10 per cent each.

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3.2.2 Material consumption by process stage

The material requirement is analyzed according to the distinct steps in the chemical synthesis.

Product	<u>Process I</u>		Process II	
Carbendazim				
Calcium cyanamide	628 kg		644 kg	
Methylchlorocarbonate	454 kg		465 kg	
o-Phenylenediamine	407 kg		417 kg	
Hydrochloric acid	213 kg		219 kg	
	1,702 kg	68.2 %	1,745 kg	43.5%
Putylcarbamyl_chloride				
Butylamine			353 kg	
Ethyl formate			393 kg	
Sulfuryl chloride			760 kg	
Sodium hydroxide			129 kg	
•			1,635 kg	40.7%
Benomyl				
Acetone	440 kg		451 kg	
Butylisocyanate	355 kg		_	
Calciumcarbonate	•		185 kg	
	795 kg	31.8%	636 kg	15.8%
Total:	2,497 kg	100.0%	4,016 kg	100.0%

The main difference between the two alternatives comes from buying butylisocyanate (process I) and in-plant synthesis of butylcarbamyl chloride. The yield of carbamylation is also lower with butylcarbamyl chloride than with butylisocyanate.

3.3 Waste streams and treatments

The following waste streams are generated during the manufacture of 1,000 kg of benomy1:

Product	Process	Ī		Process_	<u>11</u>	
Carbendazim						
Material inputs, intermediate non-defined by-products and	:5,					
wastes	31 kg			32 kg		
Methanol	33 kg			34 kg		
Calcium cyanamide excess	243 kg			249 kg		
Calcium chloride	269 kg			273 kg		
Calcium hydroxide	177 kg			183 kg		
Ammonium chloride	312 kg			321 kg		
Carbon dicxide	92 kg	1,157 kg	70.5%	\$4 kg	1,186	38.3%

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Butylcarbamoyl chloride

Material inputs, intermediates,			
by-products	45 kg		
Ethanol	223 kg		
Sulfur dioxide	309 kg		
Hydrochloric acid	176 kg		
Sodium sulfate	115 kg		
Sodium chloride	94 kg	962 kg	31.0%
		_	

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Material inputs, non-defined						
by-products, benomyl	44 kg			215 kg		
Acetone	440 kg	484 kg	29.5 %	451 kg		
Calcium chloride				205 kg		
Carbon dioxide				81 kg	<u>952 kg</u>	30.7%
Total:		1,641 kg	100.0%		3,100 kg	100.0%

3.3.1 Liquid effluent

There are two waste waters in process I. The mother liquor pumped off after the sedimentation of carbendazim contains ammonium chloride, calcium chloride and methanol. The distillation residue of acetone recovery from the benomyl mother liquor contains also ammonium chloride and calcium chloride, furthermore, unreacted organic chemicals, intermediates, non-defined by-products and finished product. About 84 per cent of the waste is inorganic salts. The share of liquid effluent in the total waste is 42 per cent.

Ethanol can be recovered as a saleable by-product in process II. The carbendazim mother liquor is the same as in process I. The benomyl mother liquor is similar in nature: sodium sulfate, sodium chloride and non-defined by-products prevail in it. A third waste water is the mother liquor of butylcarbamoyl chloride left after the decomposition of excess sulfuryl chloride. About 76 per cent of the waste is inorganic salts. The snare of liquid effluent in total waste is 43 per cent.

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3.3.2 Air pollutants

In process I, a minor quantity of carbon dioxide is produced which does not pollute the environment. The acetone loss during benomyl drying and solvent recovery operation contaminates the air. Acetone emission can be reduced mainly by recovering the solvent from the drying outlet air stream.

Waste gases, including solvent vapours, account for about 30 per cent of the total waste. Their quantity is higher in process II because sulfur dioxide and hydrogen chloride are generated during chlorination with sulfuryl chloride. Sulfur dioxide is absorbed in an alkali solution, whereas hydrogen chloride in water. The obtained sodium sulfite solution is used in other processes and hydrochloric acid is recycled into carbendazim manufacture.

3.3.3 Solid wastes

Lime sludge, containing calcium cyanamide, calcium hydroxide and some calcium carbonate, is produced during carbendazim synthesis. The share of solids in the total waste is around 26 and 14 per cent, respectively.

3.4 Industrial safety

3.4.1 Materials

Except calcium carbonate, all other chemicals are toxic, therefore benomyl production should be carried out in a closed system.

3.4.2 Chemical conversions

Acylation, benzimidazole-cyclization, formylation, chlorination and carbamoylation are carried out in multipurpose batch reactors.

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4. SUMMARY EVALUATION

Methylchlorocarbonate and butylisocyanate are both produced from phosgene, an extremely toxic chemical. They are toxic themselves and very reactive, therefore their transport is strictly regulated. Butylisocyanate is less toxic and dangerous than methylisocyanate responsible for the Bhopal disaster, nonetheless, several manufacturers have investigated the synthesis of benomyl with butylcarbamyl chloride, produced on the spot from butylamine and ethyl formate, in order to eliminate the use of butylisocyanate.

There is a significant difference between the two processes as regards material consumption and waste generation. In process I, 2,497 kg of chemical inputs are required for the production of 1,000 kg of benomyl and 1,641 kg of waste is generated. The same figures for process II are 4,016 kg and 3,100 kg, respectively. The waste streams by the state of matter are summarized as follows:

	Proce	ss I	Proces	s II
Solid	420 kg	25.6%	432 kg	13.9%
Liquid	689 kg	42.0%	1,557 kg	50.2%
Gas	532 kg	32.4%	1,111 kg	35.8%
Total	1,641 kg	100.0%	3,100 kg	100.0%

708 kg of waste can be recovered in a reusable form in process II. The quantity of hazardous waste is 968 kg with process I and 1,917 kg, of which 1,189 kg can be recycled into industrial production, with process II. Round 23 per cent more toxic waste is generated in process II than in process I. On the other hand, the feedstocks of process II are easily available (in contrast to butylisocyanate) and direct material costs are smaller than with process I, in spite of the lower yields.

Technology is available for the treatment of hazardous and toxic wastes.

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Appendix 1 to annex .. of the

ENVIRONMENT IMPACT ANALYSIS OF THE MANUFACTURE OF BENOMYL

Compound	Chemical	Molecular
	formula	weight
Ammonia	NH 3	17.03
Ammonium chloride	NH ₄ C1	53.49
Benomyl	C14H18N4O3	290.32
n-Butylamine	$H_3C(CH_2)_3NH_2$	73.14
Butylcarbamyl chloride	$H_3C(CH_2)_3NHCC10$	135.59
Butyl formamide	$H_3C(CH_2)_3NHCHO$	101.15
Butylisocyanate	$H_3C(CH_2)_3NCO$	99.13
Calcium carbonate	CaCO ₃	100.09
Calcium chloride	CaCl ₂	110.99
Calcium cyanamide	CaNCN	80.11
Calcium hydroxíde	Ca(OH) ₂	74.10
Calcium sulfate	CaSO₄	136.14
Carbendazim	C ₉ H ₉ N ₃ O ₂	191.19
Carbon dioxide	CO ₂	44.01
Ethanol	C ₂ H ₅ OH	46.06
Ethyl formate	HCOOC ₂ H ₅	74.08
Hydrogen chloride	HC1	36.46
Methanol	CH 3 OH	32.04
Methyl chlorocarbonate	C1COOCH ₃	94.50
o-Phenylessediamine	$C_{6}H_{4}(NH_{2})_{2}$	108.14
Sodium chloride	NaC1	58.44
Sodium hydroxide	NaOH	40.00
Sodium sulfate	Na 2 SO 4	142.06
Sodium sulfite	Na_2SO_3	126.06
Sulfur dioxide	SO ₂	64.07
Sulfuryl chloride	S02C12	134.96

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Reactants, products and auxiliary materials in benomyl manufacture

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Appendix 2 to annex .. of the

ENVIRONMENT IMPACT ANALYSIS OF THE MANUFACTURE OF BENOMYL

Material flow sheet

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Appendix 3 to annex .. of the

ENVIRONMENT IMPACT ANALYSIS OF THE MANUFACTURE OF BENOMYL

<u>Material balances</u> for the manufacture of 1,000 kg of benomyl (in kilogrammes)

Process I:

Water

Total process I:

i II

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1. Carbendazim (reactions a,b,1)

			Input	Output
	Calcium cyanamide		628	243
	Methyl chlorocarbona	te	454	
	Water		143	
	o-Phenylenediamine		407	
	Hydrogen chloride		213	
	Calcium chloride			269
	Calcium hydroxide			177
	Ammonium chloride			312
	Carbendazim			720
	Carbon dioxide			92
	Methanol			33
	Sub-total:		1,845	1,844
2.	Benomyl (reaction c)	<u>)</u>		
	Carbendazim		689	
	Butylisocyanate		355	
	Acetone		440	440
	Benomyl			1,044
	Sub-total:		1,484	1,484
Sun	mary process I	•		
		Inputs		Waste
		1,845		1,846
		$+\frac{1,484}{3,329}$		$+\frac{1,484}{3,330}$
	Carbendazim	-689	Carbendazim	-689
		2,640		2,641

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-143

2,497

-1,000

1,641

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Calcium cyanamide 644 249 Methyl chlorocarbonate 465 Water 147 o-Phenylenadiamine 417 Bydrogen chloride 219 Calcium chloride 183 Ammonium chloride 183 Ammonium chloride 183 Ammonium chloride 183 Carbon dioxide 94 Methanol 321 Carbon dioxide 94 Methanol 34 Carbendazime -737 Sub-total: 1,892 1,891 2. Butylamine 353 Ethyl formate 393 35 Sulfuryl chloride 760 309 Sulfuryl chloride 129 223 Sulfur dioxide 100 223 Sulfur dioxide 100 223 Sulfur dioxide 100 223 Sulfur dioxide 100 223 Sulfur dioxide 165 309 Hydrogen chloride 209 223 Sulfur dioxide 1635 1,635	1.	Carbendazim (reaction	ons a,b,l)		
Wattrin Cyananute 0+1 147 Methyl chlorocarbonate 465 Water 147 o-Phenylenadiamine 417 Bydrogen chloride 219 Calcium chloride 219 Calcium hydroxide 183 Ammonium chloride 321 Carbon dioxide 94 Methanol 23 Sub-total: 1,892 Butylamine 353 Ethyl formate 393 Solium hydroxide 129 Ethanol 223 Sulfuryl chloride 760 Sodium hydroxide 176 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 Sub-total: 1,635 Benomyl 1,635 Galcium chloride 205		Coloium evenemide		644	2/.0
Water 147 o-Fhenylenadiamine 417 Hydrogen chloride 219 Calcium chloride 183 Cantom dioxide 183 Ammonium chloride 321 Carbon dioxide 94 Methanol 219 Carbon dioxide 94 Methanol 737 Sub-total: 1,892 1,891 1,891 2. Butylamine Bthyl formate 353 Sub-total: 1,892 Sulfuryl chloride 760 Sodium hydroxide 129 Ethanol 223 Sulfur dioxide 194 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 205 Carbon dioxide 205 451 Actone 451 451 Actone 451 451 Actone 451 451 Actone 451 451 <td></td> <td>Methyl chlorocarbon</td> <td>ato</td> <td>465</td> <td>247</td>		Methyl chlorocarbon	ato	465	247
water 117 Hydrogen chloride 219 Calcium chloride 219 Calcium chloride 183 Ammonium chloride 321 Carben dioxide 94 Methanol 34 Carben dioxide 94 Methanol 34 Carbendazime 737 Sub-total: 1,892 2. Butylcarbamyl chloride 1,892 kg (reactions c.d.e) Butylamine 353 Sulfuryl chloride 393 Sulfuryl chloride 129 Ethanol 223 Sulfur dioxide 129 Ethanol 223 Sulfur dioxide 109 Hydrogen chloride 94 Sodium sulfate 115 Water 299 Butylcarbamyl chloride 654 Sub-total: 1,635 3. Benomyl (reaction f) Carbendazim 705 Butylcarbamyl chloride 451 Actone 451 Ben		Water	acc	147	
Bydrogen chloride 219 Calcium chloride 219 Calcium hydroxide 183 Ammonium chloride 321 Carbon dioxide 94 Methanol 34 Carbon dioxide 94 Methanol 321 Carbon dioxide 94 Methanol 321 Carbon dioxide 94 Methanol 321 Carbon dioxide 94 Methanol 34 Carbondazime 737 Sub-total: 1,892 Butylcarbamyl chloride 1,892 kg (reactions c.d.e) 8 Butylcarbamyl chloride 363 Sulfur dioxide 129 Ethyl formate 393 Sulfur dioxide 129 Butylcarbamyl chloride 664 Sodium sulfate 115 Water 33 Carbendazim 705 Butylcarbamyl chloride 644 Calcium carbonate 185 Calcium chloride 451 Acetone 451 Meter 33		o_Phenylenadiamine		417	
Calcium chloride 273 Calcium chloride 183 Ammonium chloride 321 Carbon dioxide 94 Methanol 34 Carbondazime 737 Sub-total: 1,892 1,891 2. Butylcarbamyl chloride 1,892 kg (reactions c,d,e) 1,891 Butylamine 353 35 Suffuryl chloride 393 35 Suffuryl chloride 129 223 Ethanol 23 223 Suffurdioxide 129 223 Suffurdioxide 129 223 Suffurdioxide 144 309 Hydrogen chloride 94 94 Sodium suffate 115 94 Suffurdioxide 1655 1,635 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 2 205 Calcium chloride 451 451 Acetone 451 451 Benomyl		Hydrogen chloride		219	
Calcium hydroxide 183 Ammonium chloride 321 Carbon dioxide 94 Methanol 34 Carbon dioxide 94 Methanol 34 Carbon dioxide 94 Methanol 34 Carbendazime 737 Sub-total: 1,892 1,891 2. Butylczrbamyl chloride 1,892 kg (reactions c.d.e) 183 Butylamine 353 35 Sulfur dioxide 760 223 Sulfuryl chloride 760 35 Sulfur dioxide 129 176 Sodium hydroxide 129 176 Sodium chloride 94 36 Sulfur dioxide 94 105 Water 29 29 Butylcarbamyl chloride 644 144 Calcium chloride 205 Water 33 205 Galcium chloride 451 451 Meter 451 451 Butylcarbamyl 1,071 33 Carbendazim 705		Calcium chloride		21/	273
Ammonium chloride 321 Carbon dioxide 94 Methanol 34 Carbendazime 737 Sub-total: 1,892 2. Butylcarbamyl chloride 1,892 kg (reactions c.d.e) Butylamine 353 Sulfuryl chloride 393 Sulfuryl chloride 393 Sulfuryl chloride 129 Ethanol 223 Sulfuryl chloride 309 Hydrogen chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) Carbendazim 705 Carbon dioxide 81 144 Calcium chloride 205 33 Water 33 205 Carbon dioxide 451 451 Acetone 451 451 Mater 1,985 1,985 Sub-total: 1,985 1,985 Sub-total: 1,985 1,985 Sub-total: 1,985 1,98		Calcium hydroxide			183
Carbon dioxide 94 Methanol 34 Carbendazime 737 Sub-total: 1,892 1,891 2. Butylcarbamyl chloride 1,892 kg (reactions c.d.e) 1,891 2. Butylcarbamyl chloride 1,892 kg (reactions c.d.e) 24 Butylamine 353 35 Ethyl formate 393 35 Soldium hydroxide 129 Ethanol 223 Sulfur dioxide 176 Sodium hydroxide 176 Sodium chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 205 Carbendazim 705 81 Mater 33 235 Sub-total: 1,985 1,635 3. Benomyl (reaction f) 205 Carbon dioxide 81 42 Acetone 451 451 Benomyl		Ammonium chloride			321
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2. <u>Butylcarbamyl chloride 1,892 kg</u> (reactions c,d,e) Butylamine 353 Ethyl formate 393 35 Sulfuryl chloride 760 Sodium hydroxide 129 Ethanol 223 Sulfur dioxide 309 Hydrogen chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride <u>654</u> Sub-total: 1,635 1,635 3. <u>Benomyl</u> (reaction f) Carbendazim 705 Butylcarbamyl chloride 644 144 Calcium carbonate 185 Calcium chloride 451 451 Benomyl <u>1,071</u> Sub-total: 1,985 1,985 <u>Summary process II</u> <u>Inputs</u> <u>Waste</u> 1,892 1,895 <u>Summary process II</u> <u>Inputs</u> <u>Waste</u> 1,892 1,891 +1,635 +1,985 <u>Summary process II</u> Carbendazim -705 Carbendazim -705 Butylcarbamyl chloride -644 Water -147 Water -62 Butylcarbamyl 4,016		Sub-total:		1,892	1,891
Butylamine 353 393 Sulfuryl chloride 35 393 35 Sulfuryl chloride 760 309 Sodium hydroxide 129 Ethanol 223 309 Bydrogen chloride 309 Bydrogen chloride 309 Sodium chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 644 144 Carbendazim 705 1,635 33 Butylcarbamyl chloride 644 144 205 Water 33 33 33 33 Carbendazim 705 81 1,071 Sub-total: 1,985 1,985 1,985 Sub-total: 1,985 1,985 1,985 Summary process II Inputs Waster -705 Butylcarbamyl -705 5,511 -705 Carbendazim -705 5,511 -705	2.	Butylcarbamyl chlor	ide 1,892 kg	g (reactions c,d,e))
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Ethyl rormate 333 33 Sulfuryl chloride 760 Sodium hydroxide 129 Ethanol 223 Sulfur dioxide 309 Hydrogen chloride 94 Sodium chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 644 144 Carbendazim 705 1645 Butylcarbamyl chloride 644 144 Calcium carbonate 185 205 Water 33 205 33 Carbon dioxide 81 451 451 Acetone 451 451 451 Benomyl		Butylamine		202	25
Sulfuryl chloride 700 Sodium hydroxide 129 Ethanol 223 Sulfur dioxide 309 Hydrogen chloride 309 Sodium chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 644 144 Carbendazim 705 644 144 Calcium chloride 205 33 205 Water 33 205 33 205 Water 33 205 451 451 Mater 451 451 451 451 Sub-total: 1,985 1,985 1,985 Sub-total: 1,985 1,985 5,511 Carbendazim -705 Carbendazim -705 Butylcarbamyl Butylcarbamyl -644 -644 Water -644 chloride -644 Water -62 Benomyl -1,000 <td></td> <td>Ethyl formate</td> <td></td> <td>393</td> <td>35</td>		Ethyl formate		393	35
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hydrogen chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 644 144 Carbendazim 705 705 Butylcarbamyl chloride 644 144 Calcium carbonate 185 205 Calcium chloride 33 205 Water 33 205 Carbon dioxide 81 Acetone Acetone 451 451 Benomyl 1,071 1,985 1,985 Sub-total: 1,892 1,891 1,635 Sub-total: 1,892 1,891 1,635 Sub-total: 1,985 5,511 5,511 Carbendazim -705 Carbendazim -705 Butylcarbamyl Butylcarbamyl 5,511 -705 Carbendazim -705 Carbendazim -705 Butylcarbamyl Butylcarbamyl -62 5,511 Carbendazim -644 chlo		Sulfur dioxide			309
Sodium chloride 94 Sodium sulfate 115 Water 29 Butylcarbamyl chloride 654 Sub-total: 1,635 1,635 3. Benomyl (reaction f) 644 144 Carbendazim 705 1,635 Butylcarbamyl chloride 644 144 Calcium carbonate 185 205 Calcium chloride 205 33 Carbon dioxide 81 Acetone Acetone 451 451 Benomyl		Hydrogen chloride			1/0
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Subylearbanyl chloride		Water Putuloonhomul oblog			29 651
Sub-total: 1,635 1,635 3. Benomyl (reaction f) Carbendazim 705 Carbendazim 705 144 Calcium carbonate 185 205 Water 205 33 Carbon dioxide 81 Acetone 451 451 Benomyl 1,071 5 Sub-total: 1,985 1,985 Summary process II Inputs Waste 1,892 1,891 +1,635 +1,635 +1,985 5,512 Summary process II Super term -705 Carbendazim -705 Carbendazim -705 Carbendazim -705 Butylcarbamyl Butylcarbamyl -705 Carbendazim -644 chloride -644 Water -147 Water -62 Benomyl -1,000 -1,000 -1,000		Butylcarbamyi chior	lae		4
3. Benomyl (reaction f) Carbendazim 705 Butylcarbamyl chloride 644 144 Calcium carbonate 185 Calcium chloride 205 Water 33 Carbon dioxide 451 451 Benomyl 1 1,071 Sub-total: 1,985 1,985 Summary process II Negative 1,891 +1,635 +1,985 +1,635 +1,985 +1,985 5,512 5,511 Carbendazim -705 Carbendazim -705 Butylcarbamyl Butylcarbamyl chloride -644 chloride -644 Water -147 Water -62 Benomyl -1,000		Sub-total:		1,635	1,635
3. <u>Benomy1</u> (reaction 1) Carbendazim 705 Butylcarbamyl chloride 644 144 Calcium carbonate 185 Calcium chloride 205 Water 33 Carbon dioxide 451 451 Benomy1 1.071 Sub-total: 1,985 1,985 Summary process II 1.071 Sub-total: 1,985 1,985 Summary process II 1.891 +1,635 +1,985 5,511 Carbendazim -705 Carbendazim -705 Butylcarbamy1 Butylcarbamy1 chloride -644 chloride -644 Water -147 Water -62 Benomy1 -1,000	2	Personal (marching f	``		
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Calcium chloride 205 Water 33 Carbon dioxide 81 Acetone 451 Benomyl 1,071 Sub-total: 1,985 Summary process II 1,892 Inputs Waste 1,892 1,891 +1,635 +1,635 +1,985 5,512 Carbendazim -705 Carbendazim -705 Carbendazim -644 water -147 Water -147 Water -1,000		Calcium carbonate		185	
Water 33 Carbon dioxide 81 Acetone 451 451 Benomy1 1,071 Sub-tota1: 1,985 1,985 Summary process II 1,892 1,891 Inputs Waste 1,985 Summary process II 1,892 1,891 Carbendazim -705 Carbendazim -705 Carbendazim -705 Carbendazim -705 Butylcarbamy1 Butylcarbamy1 -644 chloride -644 Water -147 Water -62 Benomy1 -1,000		Calcium chloride			205
Carbon dioxide 81 Acetone 451 451 Benomyl 1,071 Sub-total: 1,985 1,985 Summary process II Inputs Waste 1,892 1,891 +1,635 +1,635 +1,985 5,512 Carbendazim -705 Carbendazim -705 Carbendazim -644 chloride -644 Water -147 Water -147 Benomyl -1,000		Water			33
Acetone 451 451 Benomy1 $1,071$ Sub-total: $1,985$ Summary process II Inputs Waste $1,892$ $1,891$ $+1,635$ $+1,635$ $+1,985$ $5,512$ Carbendazim -705 Carbendazim -705 Carbendazim -705 Buty1carbamy1 Buty1carbamy1 chloride -644 Water -147 Water -62 Benomy1 $-1,000$		Carbon dioxide			81
Benomy1 $1,071$ Sub-tota1: $1,985$ Summary process II $1,985$ InputsWaste $1,892$ $1,891$ $+1,635$ $+1,635$ $+1,985$ $5,512$ Carbendazim -705 Butylcarbamy1Butylcarbamy1chloride -644 Water -147 Water -62 Benomy1 $-1,000$		Acetone		451	451
Sub-total: $1,985$ $1,985$ Summary process IIInputsWaste $1,892$ $1,891$ $+1,635$ $+1,635$ $+1,985$ $5,512$ Carbendazim -705 ButylcarbamylButylcarbamylchloride -644 water -147 Water -62 Benomyl $-1,000$		Benomy1			1,071
Summary process II Inputs Waste 1,892 1,891 +1,635 +1,635 +1,985 5,512 5,512 5,511 Carbendazim -705 Butylcarbamyl Butylcarbamyl chloride -644 Waste -644 Waste -644 Summary process 1,891 Carbendazim -705 Carbendazim -705 Carbendazim -705 Butylcarbamyl Butylcarbamyl chloride -644 Water -147 Water -62 Benomyl -1,000		Sub-total:		1.985	1,985
Summary process II Inputs Waste 1,892 1,891 +1,635 +1,635 +1,985 5,512 5,512 5,511 Carbendazim -705 Butylcarbamyl Butylcarbamyl chloride -644 Water -147 Water -62 Benomyl -1,000				-,, , , , , , , , , , , , , , , , , , ,	
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$			Inputs		Waste
$\begin{array}{cccccccccccccccccccccccccccccccccccc$			1,892		1,891
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$			+1,635		+1,635
5,5125,511Carbendazim-705Carbendazim-705ButylcarbamylButylcarbamyl-644chloride-644chloride-644Water-147Water-62Benomyl-1,000-1,000			+1,985		+ <u>1,985</u>
Carbendazim-705Carbendazim-705ButylcarbamylButylcarbamylchloride-644water-147Water-62Benomyl-1,000			5,512		5,511
Butylcarbamyl Butylcarbamyl chloride -644 Water -147 Water -62 Benomyl -1,000		Carbendazim	-705	Carbendazim	-705
chloride -644 chloride -644 Water -147 Water -62 Benomyl -1,000		Butylcarbamyl		Butylcarbamyl	
Water -147 Water -62 Benomyl $-1,000$		chloride	-644	chloride	-644
Benomyl $-1,000$		Water	147	Water	-62
		T		Benomyl	- <u>1,000</u>
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