New technologies, emission levels and overall environmental effects of wood-based bioproduct plants

English summary

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Introduction

This is a summary of the report *New technologies, emissions levels and overall environmental effects of wood-based bioproduct plants* [1]. The report was prepared as part of the OHKE project *The development of the licensing and supervision of new bioproduct plants in the chemical forest industry*, financed by the Ministry of the Environment. The duration of the project was from May 2020 to August 2022. The Centre for Economic Development, Transport and the Environment for Southeast Finland and the Finnish Environment Institute (SYKE) have been responsible for the preparation and implementation of the project. In addition, experts from the Ministry of the Environment, Aalto University, LUT University, the Regional State Administrative Agency for Northern Finland, the Finnish Forest Industries Federation, the Finnish Association for Nature Conservation (FANC) and several forest industry companies were involved in the project.

The aim of this project was to provide information about the products, the production volume and process technical solutions of bioproduct plants. An effort was made to identify the direct and indirect effects of new biorefining processes on the emissions of the chemical forest industry. Information on the processes and emissions of bioproduct plants was produced to support the preparation of Best Available Techniques Reference documents (BREFs) of the EU Industrial Emissions Directive (2010/75/EU), and as background material for permit consideration and supervision.

Materials

The report only includes new wood-based raw material processing techniques that are applied or under development. Descriptions of production techniques are limited to new mill projects and processes that operate either independently or integrated into a traditional pulp mill. For the sake of comparison, emission data and production capacities are presented for both new wood-based raw material processes and traditional kraft pulp mills.

The following techniques were reviewed: the recovery of lignin, gasification of bark, sulphuric acid production, refining of tall oil, bioconversion, textile fibre production, membrane technology and green hydrogen production. For the technical descriptions, information was obtained from four operators. In addition, information was collected from literature sources.

Emission data were collected from ten plants in Finland and Sweden. Emission and production data are based on environmental monitoring reports submitted by operators to the authorities. The data covers the years 2015-2021. This report focuses on the emission components based on the Pulp and Paper BAT conclusions (2014/687/EU).

Results

Emissions to air and water are presented in figures 1, 2 and 3.

* not all plants produce all products

					Emissions to air in 3 % O_2								Emissions to water					
					[mg/m^{3}n]	[mg/m^{3}n]	[mg/m^{3}n]	[mg/m^{3}n]	[mg/m^{3}n]	[t/a]	[t/a]	[t/a]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]
Process	**Raw material**	**Raw material [t/a]**	**Products***	**Capacity [t/a]**	**SO_2**	**TRS**	**NO_X**	**Particles**	**CO**	**CO_2**	**CO_2 fossil**	**CO_2 biogenic**	**COD**	**BOD**	**Solids**	**N**	**P**	**Oily substances**
Tall oil distillery	Crude tall oil	98 000 -183 000			0-1230	4-10	39-258	8-47	2-89	12 000-20 000	0-15 800	0-24 000	700-4200	260-1800	40-1200	0.06-12.6	0.09-16.0	40-270
			Crude terpentine	max. 4100														
			Fatty acid	max. 103 500														
			Tall oil	max. 13 000														
			Distilled tall oil	max. 164 000														
			Resin pitch	max. 25 000														
			Resin soap	max. 44 000														
			Resin esters	max. 40 000														
			Ester dispersions	max. 9000														
			Resin products	max. 180 000														
			Tall oil resin	max. 75 000														
			Tall oil pitch	max. 60 000														
			Tall oil fatty acid	unknown														
			Tall oil products	unknown														
Biorefinery (tall oil)	Crude tall oil	no data	Bionafta and biodiesel	130-180 000	5-21	7	43-137	2--37	1-22	53 700-84 500	53 000-61 000	700-23 400	1200-1900	600-900	90-150	40-60	0.1-0.2	no data
Fast pyrolysis		no data	Bio oil	24 000	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
Bioconversion	Wood-based biomass	no data			no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
			Bioethanol	8000														
			Lignin (45 %-55 % dry matter)	30 000-36 000														
			Turpentine	190														
			Biogas (50 % CH_4)	1 100 000 m^3/a														

Figure 1. Raw materials, products, production capacities and emissions to air and water in tall oil distilleries, biorefineries, fast pyrolysis plants and bioconversion plants.

*not all plants produce all products
[1] natural gas/lignin as fuel

Process	Products*	Capacity [t/a]	Capacity representing the measured emissions [t/a]	Emissions to air in 6 % O_2 [mg/m^{3}n]									
				SO_2		TRS		NO_x		Particles		CO	
				Lime kiln	Recovery boiler	Lime kiln	Recovery boiler	Lime kiln	Recovery boiler	Lime kiln	Recovery boiler	Lime kiln	Recovery boiler
Kraft pulping process				5-67	3-7	2-7	3-6	64-440	168-215	1-34	18-82	12-509	32-501
	Kraft pulp (bleached and unbleached)	180 000-1 100 000	**air:** 680 000-800 000 t/a (realised: 557 000-776 000) **water:** 800 000 (realised 650 000-776 000)										
	Market kraft pulp	max. 105 000	0										
	CTMP	max.350 000	0										
	Pulp from sawdust	max. 180 000	0										
	Recycled fiber	max. 55 000	0										
	Tall oil	unknown	unknown										
	Turpentine	unkwnown, approx. a few thousands tonnes	unknown										
	Biomethanol	max. 5000	0										
Kraft pulping process (gasification of bark)				5-20	no data	no data	no data	116-395	108-238	7-223	6-118	7-500	11-1072
	Kraft pulp	310 000-690 000	310 000-690 000 (realised: 342 000-602 000)										
	Turpentine	max. 1200	max. 1200										
	Tall oil	15 000	15 000										
Kraft pulping process (recovery of lignin)				2-11 ; 2-39 [1]	0.6-33	0.2-17 ; 1.5-6 [1]	0.1-2.8	187-433 ; 80-128 [1]	111-175	1-125; 1-302 [1]	9-141	3-461 ; 4-313 [1]	4-593
	Kraft pulp	380 000 - 470 000	380 000 (realised: 342 000-370 000)										
	Lignin	25 000-50 000	50 000										
Bioproduct plant (gasification of bark and sulphuric acid plant)				0.7-6	no data	1.5-3.1	0.23-0.85	440-590	144-168	18-22	1-4	4-43	140-660
	Kraft pulp (softwood)	max. 1 180 000	1 180 000 (realised: 362 000-1 100 000)										
	Kraft pulp (hardwood)	max. 320 000	320 000										
	Kraft pulp (bleached)	max. 1 300 000	0										
	Tall oil	86 000	86 000										
	Turpentine	7000	7000										
	Product gas (side product)	approx. 80 MW	80 MW										
	Sulphuric acid (side product)	max. 16 000	16 000										
Sulphite pulp process (bioconversion, recovery of lignin)				no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
	Sulphite pulp	230 000											
	Lignosulphonate	75 000											
	Bioethanol	17 000											
Fluting plant				no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
	Semipulp	300 000-314 000											

Figure 2. Raw materials, products, production capacities and emissions to air in kraft pulping processes.

***not all plants produce all products**

[1] natural gas/lignin as fuel

Process	Products*	Capacity [t/a]	Capacity representing the measured emissions [t/a]	Emissions to water (from wastewater treatment plant) [kg/ADt]								Emissions to water (other sources) [kg/ADt]				
				COD	BOD	Solids	N	P	AOX	S	Na	BOD	Solids	N	P	Na
Kraft pulping process				11-17	0.16-0.28	0.38-0.53	0.071-0.099	0.0036-0.0085	0.10-0.16	no data	24.0-27.3	0.053-0.31	0.043-0.30	0.014 0.098	0.00034-0.0013	0.11-0.49
	Kraft pulp (bleached and unbleached)	180 000-1 100 000	**air:** 680 000-800 000 t/a (realised: 557 000-776 000) **water:** 800 000 (realised 650 000-776 000)													
	Market kraft pulp	max. 105 000	0													
	CTMP	max.350 000	0													
	Pulp from sawdust	max. 180 000	0													
	Recycled fiber	max. 55 000	0													
	Tall oil	unknown	unknown													
	Turpentine	unkwnown, approx. a few thousands tonnes	unknown													
	Biomethanol	max. 5000	0													
Kraft pulping process (gasification of bark)				4.8-13	0.2-1.2	0.5-3.1	0.13-0.32	0.009-0.030	0.14-0.18	3.7-15	19.9-26.5	0.0002-0.15	0-0.017	0.0031-0.0082	0.00014-0.00071	no data
	Kraft pulp	310 000-690 000	310 000-690 000 (realised: 342 000-602 000)													
	Turpentine	max. 1200	max. 1200													
	Tall oil	15 000	15 000													
Kraft pulping process (recovery of lignin)				17-19	0.13-0.35	0.25-1.53	0.039-0.12	0.018-0.023	0.09-0.17	10-16	22.9-29.9	0.012-0.12	0.12-0.26	0.0037-0.040	0.00044-0.00096	0.076-0.93
	Kraft pulp	380 000 - 470 000	380 000 (realised: 342 000-370 000)													
	Lignin	25 000-50 000	50 000													
Bioproduct plant (gasification of bark and sulphuric acid plant)				6.0-7.2	0.10-0.14	0.48-0.53	0.054-0.089	0.0049-0.0065	0.089-0.12	no data	no data	no data	no data	no data	no data	no data
	Kraft pulp (softwood)	max. 1 180 000	1 180 000 (realised: 362 000-1 100 000)													
	Kraft pulp (hardwood)	max. 320 000	320 000													
	Kraft pulp (bleached)	max. 1 300 000	0													
	Tall oil	86 000	86 000													
	Turpentine	7000	7000													
	Product gas (side product)	approx. 80 MW	80 MW													
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Sulphite pulp process (bioconversion, recovery of lignin)				no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
	Sulphite pulp	230 000														
	Lignosulphonate	75 000														
	Bioethanol	17 000														
Fluting plant				no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
	Semipulp	300 000-314 000														

Figure 3. Raw materials, products, production capacities and emissions to water in kraft pulping processes.

Conclusions

The recovery of lignin, gasification of bark and sulfuric acid production might have an influence on the mass and energy balance of the main plant. Refining of tall oil, bioconversion, textile fibre production, membrane technology and green hydrogen production can operate as independent processes that have no impact on the main plant's mass and energy balance. A summary of the environmental benefits and overall environmental effects achieved by different techniques is presented below.

Recovery of lignin

+ Lignin can be used to replace fossil fuels and products made from fossil raw materials.
+ Lignin has versatile application possibilities in products that bind carbon for a long time.
– The removed lignin has an impact on the energy and material balance of the pulp mill and the properties of black liquor.
– Sulphuric acid is used in the process, which can result in increased sulphur emissions.
– Recovery of lignin increases the chemical load of the plant in terms of sulphuric acid, carbon dioxide and lye (NaOH).

Gasification of bark

+ The product gas can replace fossil fuels.
+ With gasification of bark, a sufficiently high combustion temperature can be achieved, and the product gas can be used as fuel for the lime kiln.
+ SO_2 emissions decrease if the product gas is used to replace sulphurous heavy fuel oil.
+ Better energy efficiency is achieved in gasification of bark than in direct combustion of bark.
– The volume of flue-gas from the lime kiln increases, and the production capacity of the kiln might decrease when the product gas is used.
– The nitrogen emissions from the lime kiln increase when the product gas is used.
– Foreign substances from the bark enter the lime kiln when product gas is used and consequently, the need to open the lime cycle increases approximately 5-10 %.
– The method requires more process engineering solutions than, for example, direct combustion of bark or other fuels.

Sulphuric acid production

+ Production of sulphuric acid from flue-gas reduces emissions released into the air.
+ Improves the plant's chemical cycle.

Refining of tall oil

+ Products from tall oil can replace fossil raw materials in the production of plastic products and fuels.

Bioconversion

+ Products from bioconversion can replace fossil fuels, reducing the need for fossil fuels.
+ An alternative to biofuel production.

Textile fibre production

+ The recycling possibilities of solvents and water reduce the amount of waste generated in the process and can enable a more closed chemical cycle at plant level.
+ Norratex textile fibre: versatile raw material possibilities and carbon bisulphide (CS_2) is not needed in the production, in contrast to the production of traditional viscose.
– Some of the used solvents are dangerous for the environment.

Membrane technology

+ Possible to reduce the amount of phosphorous released into the water without using precipitation chemicals.
+ Emissions to water decrease when more water is recycled at the factory, and the amount of wastewater is reduced.
+ Compounds separated by membranes can be collected and reused, or they can be developed to new by-products.
– The pressure difference required by the membranes requires the use of pumps, which increases the electricity consumption.
– Membrane fouling requires aeration and cleaning chemicals, which can increase the electricity consumption, the need for chemicals and the amount of wastewater.
– The waste formed by the concentrate.
– A possible source of microplastics.

Green hydrogen production

+ Hydrogen produced with water electrolysis and renewable energy does not produce carbon dioxide emissions.
– The electricity consumption increases.

References

1. Vehmaanperä P., Oksanen, K., Ålander T., Tuominen L., Hiltunen K., Ojanen P., Toikka M., Häme K., Monto E., Rantala J., Jouttijärvi T., Forsius K., Vähä E. 2022. New technologies, emissions levels and overall environmental effects of wood-based bioproduct plants (in Finnish). Centre for Economic Development, Transport and the Environment for Southeast Finland. Reports 79/2022. ISBN 978-952-398-102-7. Available at: https://www.ely-keskus.fi/kaakkois-suomi-biobat-hanke

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