Institut für Ökologie und Politik GmbH

Best available techniques in the Printing Industry

German background paper for the
BAT-Technical Working Group
"Surface treatment using organic solvents"
organised by the European IPPC Bureau

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Commissioned by the
Federal Environmental Agency, Berlin, Germany

This background paper is based on the following research project of the Federal Environmental Agency, Berlin, Germany

Funding No.: 200 94 324

Integrated Pollution Prevention and Control in selected Industrial Activities

- Installations for Surface Treatment using organic solvents for Dressing, Impregnating, Printing, Coating -

Part II – "Printing"

Hamburg/Berlin

February 2003

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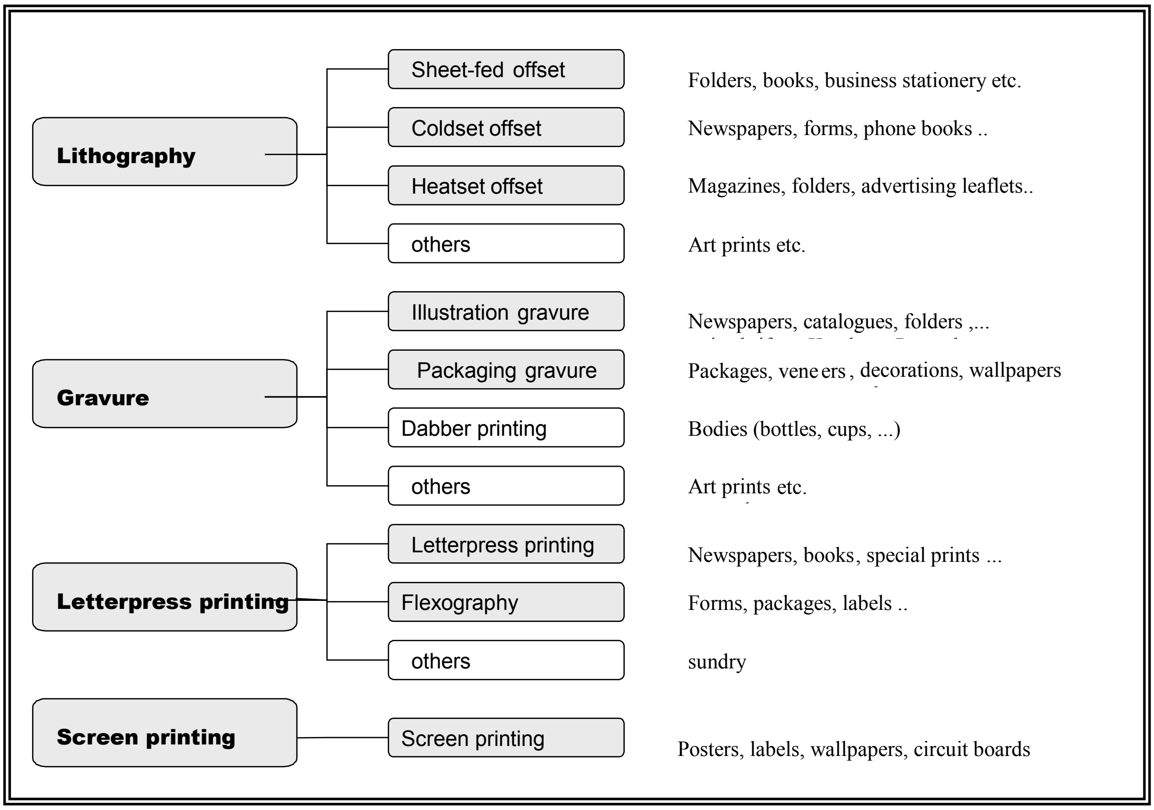
1. Basic information about printing industry

1.1 Processes and techniques

Printing technology is classified into four main printing methods and a range of less usual methods. Many of these less customary processes do not play an important role in today's industrial production because of their low material flow and energy flux. In the following illustration the relevant processes for the BAT discussion are marked grey. For each of these processes some keywords about essential product groups are listed.

Fig. 1: Main printing processes with process variants



1.2 IPPC relevant plants

Annex 1 No. 6.7 of the IPPC Directive (1996/61/EC) is valid for all printing plants which operate above the solvent comsumption capacity of > 150 kg/h or > 200 t/a. The following table shows the yearly ink consumption thresholds of different types of printing industry plants that use to go along with an exceed of the VOC thresholds of the IPPC directive.

Tab. 1: Estimation of ink consumption quantities that usually go along with an exceed of a yearly VOC consumption of 200 t

No.	Machine constellation	Ink consumption limit calculated [t/a] (rounded)
1	Illustration gravure	> 120
2	Heat set web offset	> 380
3	Package gravure solvent-based	> 115
4	Package gravure water-based	> 1,175
5	Package flexography solvent-based	> 130
6	Package flexography water-based	> 1,175

[ÖKOPOL/B.A.U.M. 1997]

The following table presents how many printing plants of the different plant constellations in Germany will be regulated by the IPPC Directive.

Tab. 2: Range of IPPC Directive in the German printing industry

Kind of plant	In total	IPPC plants	Plants according to IPPC Directive 1999/13/EC
Graphic printing			
Illustration gravure	16	**16**	16
Coldset offset	200	none	excluded by definition
Sheet-fed offset	ca 10,000	probably none	excluded by definition
Heat set offset	160	**ca 100**	160
Continuous printing	250	none	excluded by definition
Letterpress printing	2	none	excluded by definition
Package printing			
Package gravure	ca 100	**ca 30**	ca 80
Package flexography	ca 350	**ca 30-40**	ca 150

[Estimation ÖKOPOL]

On the background of the mentioned definition coldset offset and sheet-fed offset printing plants in Germany are not IPPC relevant. Both printing methods apply only mineral oil based printing inks with a steam pressure lower than 0.01 kPa, thus they are consequently not considered as VOC.[1]

1 Nevertheless also in these printing processes often relevant quantities of VOC-containing substances are used (especially cleaning agents and damping solution additives in sheet-fed offset). The experts have no knowledge of coldset and sheet-fed plants in Germany in which the quantity of VOC containing substances exceeds the emission limits of the IPPC Directive (see Tab. 5).

Package production printing plants are often operating closely combined with other solvent emitting processes (like gluing, laminating, coating). Therefore small printing plants may be part of an IPPC plant too, depending on the national interpretation and implementation of the plant definition.

Corresponding to the presented range of the IPPC Directive in the German printing industry the following types of printing plants are treated in this document:

- Heatset printing plants
- Package printing plants
- Illustration gravure plants

1.3 Specific method of description

Production in the printing industry is characterised on one hand by high-tech printing processes in very specialised printing machines, on the other hand by a variety of partly handicraft auxiliary processes. In these printing plants a wide spectrum of products with quite different „quality aims“ is manufactured while very different process combinations are applied.

In order to name comparable, specific consumption and emission values which make sense, this BAT description uses a special structure.

1. For each of the examined printing processes the production processes are differentiated into main processes and auxiliary processes. The main processes are directly coupled with the printing process so that specific relationships between consumption and emission can be depicted. The auxiliary processes, in the contrary, depend more on the way of handling and on the established plant procedures than on the printing process.
2. In order to describe the main processes, machine configurations are used that represent a progressive state of the art in the respective printing process (“model plant”). For each machine configuration a typical product spectrum is assumed as the consumption quantities (and the emission values) – as mentioned above - depend a lot on the products.
3. In addition to the detailed description of the main processes illustrated by the model plants, there are also given examples of complete plants (“reference plants“), in which the auxiliary processes are included.

The description of the material flow and energy flux of the model plants is based on a solid basis of average values from a great number of printing plants. The investigation of these values refers to

- the ÖKOPOL branch database with reference values of ca 250 printing plants,
- the enquiry of supplementary data in suitable companies
- a great number of interviews and conversations with experts from graphic arts’ suppliers

2. Heatset web offset printing plants

2.1 Printing inks

In heatset web offset printing special heatset web offset printing inks are used. They dry mainly physically by evaporation of the (high boiling) component of the solvent. For this purpose the printed paper web is heated in a hot-air dryer at a circulating air temperature of 190° - 250°C. It remains in the dryer for about 0.7 – 1.0 seconds. The paper web leaves the dryer with a temperature of 90-140 °C.

The following table presents an average receipt for heatset web offset printing inks.

Tab. 3: Average basic receipt for heatset web offset printing inks

Component	**Contents**	**Concentration (wt.-%)**
Binding agent - Solvent component - Binding agent component	 Mineral oils (boiling points ca 240°C - 300°C) Resins, vegetable oils	 30 – 35% 45 – 50%
Colorants	Nearly exclusively organic pigments (mainly the 3 process colours and black are used)	15 – 25%
Colour auxiliary agents	siccatives (metal soaps), anti-oxidising agents (e. g. butyl hydroxy toluene, hydroquinone), anti-skinning agents (e. g. cyclohexanon oxime), complex formers (e. g. EDTA, tartrates)	< 10%
Physical properties: Solids content ca 67%; net calorific value ca > 36 MJ/kg; flash point > 100°C		

During printing not only ink but also damping solution is applied to the printing material. Special damping solution additives as well as alcohols are added to the raw water. In most cases isopropanol is used (2-propanol, VOC because of its steam pressure of 4.3 kPa). This substance is added in its pure form to the damping solution in a concentration of ca 5% to 15%[2]. Isopropanol improves the wetting of the printing plate, acts as a biocide against the growth of microbes in the damping solution and cools the printing unit by its evaporation.

Apart from isopropanol ca 1-3% other dampening solution additives[3] are mixed with the raw water. They have wide-spread functions, e. g. stabilisation of the pH value, the improvement of wetting properties and corrosion protection of the printing form.

After printing and ink drying often an aqueous silicon emulsion is applied in order to improve the set-off (above all to prevent adhesion of the printed pages).

[2] In Germany the concentration is limited to a maximum of 8 % by the implementation of the [VOC Directive 1996] .

[3] These damping solution additives can contain VOC concentrations of up to 15 wt. -%.

2.2 Printing presses

2.2.1 Installed machines

The following list presents the classification, measurements and market situation of heatset web offset printing presses in Germany.

Tab. 4: Format classes, typical web breadths and market situation of heatset web offset printing presses

Format class[DIN A4 pages]	Web breadth[cm]	Share of all machines
8-pages-machines (lying)	67.3	15 %
16- pages-machines (standing)	96.5	44 %
24- pages-machines (standing)	145.0	4 %
32- pages-machines ((lying)	126.0	26 %
48- pages-machines (standing)	145.0	6 %
64- pages-machines (standing)	180.0	5 %

[CN-Paper 2001]

2.3 Employment of VOC

While there are no VOC emissions from offset printing inks at ambient temperatures, VOC emissions arise from the heatset colours under manufacturing conditions (in the dryer by heating up of the mineral oil components). Furthermore some of the additives used in heatset web offset printing cause VOC emissions already at ambient temperatures because they have a steam pressure of more than 0.01 kPa at a normal pressure and a temperature of 20°C. The following table gives an overall picture of typical VOC-containing input substances and average input quantities, in relationship to the ink quantity.

Tab. 5: VOC-relevant input substances in heatset web offset printing and specific input quantity in relationship to the ink input

Substance	**Steam pressure** [at 20°C]	**Use**	**Specific input** [Wt.-% in relationship to the total ink input as 100%]
High boiling mineral oils (in ink and varnish)	< 0.01 kPa, > 0.01 kPa in the dryer	Ink solvent, by 90 % evaporated in the hot air dryer at 190° - 250°C circulating air temperature	30.0 – 35.0 %
Isopropanol (in the damping solution)	4.3 kPa	Reduction of the damping solution 's surface tension, cooling effect by evaporation, prevention of microbial growth	18.0 – 21.0 %
Mineral oil or vegetable oil based solvents with different steam pressures (as cleaning agents)	A I: > 1.8 kPa A II: 0.3 – 1.0 kPa A III: 0.04 – 0.15 kPa HCA: 0.002 – 0.03 kPa VCA: < 0.01 kPa	Cleaning of ink containing machine parts during printing (interim cleaning) Cleaning of ink containing and other machine parts after printing (basic cleaning)	In total: 4.5-6.5 % AI: 12.9% AII: 36.3% AIII: 39.2% HCA: 9.7% VCA: 1.9%
Classification of cleaning agents according to the flash point: AI = < 21°C, A II = 21° until < 55°C, A III = 55°C until 100°C, HCA = High Boiling Cleaning Agents (flash point > 100°C), VCA = Vegetable oil based Cleaning Agents (flash point >> 100°C)			

[ÖKOPOL 1999]

For most of the products ink application is less than 2 g/m^2 on each side.

Important for the environmental efficiency of the whole plant is the capture rate of the exhaust gas treatment plant with regard to the VOC quantities generated during the printing process – the VOC quantities not captured by the exhaust gas treatment plant are fugitive emissions escaping through the ventilating system.

Tab. 6: Typical capture rates of different VOC emission

VOC-containing substances	**Capture rate**
VOC from inks and varnishes	≤ 100 %
VOC from damping solution additives	≤ 10 %
VOC from cleaning agents used for automatic interim cleaning	≤ 15%
VOC from cleaning agents used for interim cleaning by hand	ca 0 %
VOC from cleaning agents used for basic cleaning	ca 0 %

[ÖKOPOL 1999]

Emissions not captured by exhaust gas treatment arise from:

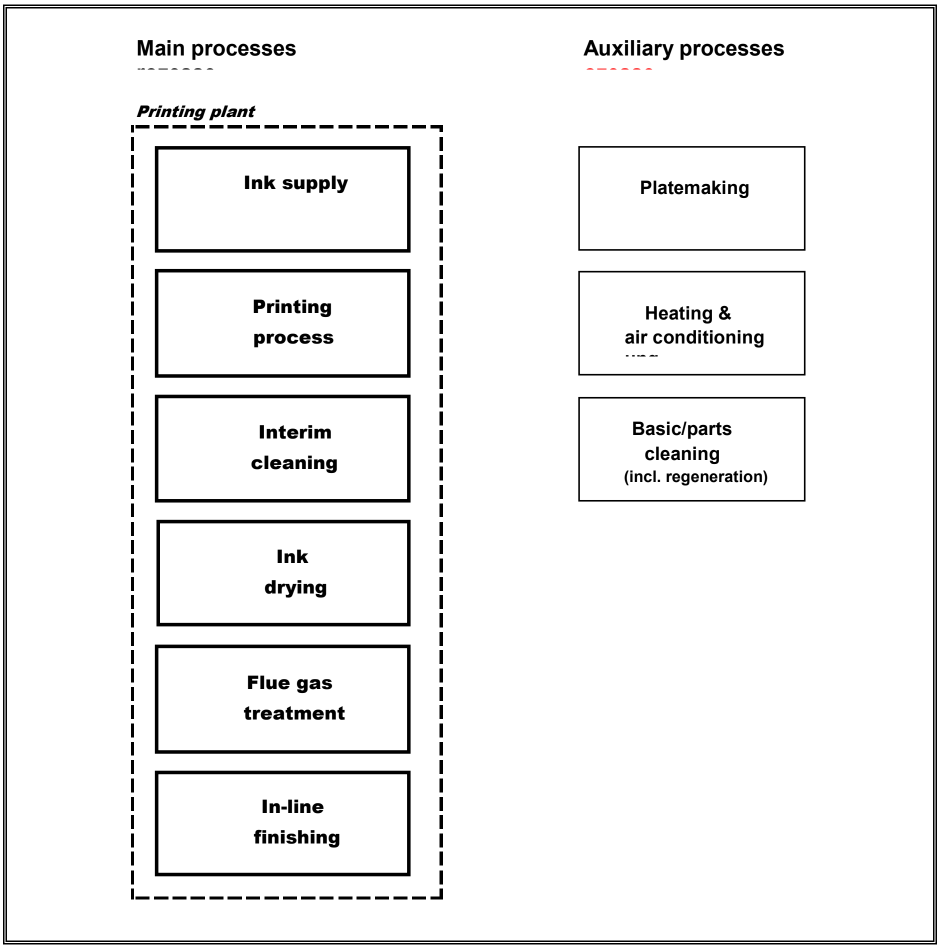
- the fact that a part of the VOC generated in the printing process is not drawn into the drying tunnel (esp. isopropanol and VOC out of cleaning agents);
- the use of VOC containing substances in a machine part while this part is not connected to the flue gas scrubber (e.g. during basic cleaning).

2.4 Process scheme and environmental impact

2.4.1 Scope of the BAT study

The following illustration shows the essential manufacturing processes in a heatset web offset printing plant which is typical of the branch. In modern heatset web offset printing plants the number of processes coupled directly to the printing process is relatively high in opposition to other printing processes. Especially flue gas treatment is a regular part of a plant in Germany.

Fig. 2: Process scheme heatset web offset printing plant



[ÖKOPOL 2002]

2.4.2 Environmental impact

The following two tables present a summary of the relevant environmental impacts of the different processes.

Tab. 7: Environmental impacts by the main processes of a heatset web offset plant

Process	Environmental medium	Relevance	Explanations
Ink supply	Emissions	-	
	Waste	+	Ink waste because of ink ageing (especially rarely used colours); waste metal containers when inks are purchased in non-returnable containers
	Waste water	-	
	Energy	-	
Printing process	Emissions	++	Ca 90 % of isopropanol of the damping solution (ca 10% get to the flue gas treatment); the total depends on the percentage of isopropanol in the damping solution
	Waste	+	Start-up waste and misprints because of printing difficulties
	Waste water	-	
	Energy	+	Rising demand for electricity especially because of direct drive and automation with compressed air demand Rising demand of cooling because of increasing machine velocities
Interim cleaning	Emissions	+	Amount depends on the cleaning technique and the employed cleaning agents
	Waste	+	Dependent on the cleaning technique: used solvent cloths, solvent-water-mixtures; amount depends on the handling
	Waste water	-	
	Energy	-	
Ink drying	Emissions	-	No emissions because of enclosed dryer
	Waste	-	
	Waste water	-	
	Energy	+	Depends on the dimensioning of the dryer
Flue gas treatment	Emissions	(+)	Modern plants are sure to meet emission values of < $20 g/m^2$
	Waste	-	
	Waste water	-	
	Energy	(+)	Depends on driving style and dimensioning of the plant (under best conditions mainly authothermic process with energy recovery)

Process	Environ-mental medium	Relevance	Explanations
Finishing	Emissions	(+)	Partly fine dust out of the folding unit; dependent on the paper quality
	Waste	(+)	Cutting and punching waste, mostly unimportant quantities; dependent on the products
	Waste water	-	
	Energy	-	

Tab. 8: Environmental impacts in the auxiliary processes of a heatset web offset plant

Process	Part of the envi-ronment	Relevance	Explanations
Platemaking	Emissions	(+)	Partly low VOC concentrations (< 5%) in the decoaters
	Waste	+	Ca 100 – 200 ml/m^2 used decoaters
	Waste water	+	Ca 15 l/m^2 rinsing water
	Energy	-	
Air conditioning	Emissions	-	
	Waste	-	
	Waste water	(+)	Low quantities of rinsing water from dampening and air condi-tioning
	Energy	+	Depends on the building and the energy concept
Basic cleaning	Emissions	+	VOC emissions dependent on the employed agents and their handling
	Waste	+	Dependent on the cleaning technique: used solvent cloths, solvent-water-mixtures; amount depends on the handling
	Waste water	+	From emptying and rinsing of the damping systems, partly high contamination with AOX and copper (>> 1 mg Cu/l and >> 1 mg AOX/l), therefore in Germany considered as waste
	Energy	-	

2.5 Up-to-date consumption and emission values

2.5.1 Model plant

As a model plant, a combination of two printing presses is chosen, that is widely spread in the branch and operated in a progressive way.

Tab. 9: Basic data of the heatset web offset model plant

Machines	2 x 32-pages heatset web offset machine; 4 blanket-to-blanket-units at a time, web breadth: 1260 mm, cylinder circumference: 890 mm; max. web velocity 17 m/s, average velocity ca 13 m/s at production run Total power supply: 1,134 kW for web velocities until 14.8 m/s; Electricity consumption at an average web velocity of 13 m/s: 996 kW Of which ca: 2 x 470 kW power supply printing press (2 x 295 kW motor power supply, 2 x 120 kW auxiliary drives (printing unit/auxiliary aggregates/control), 2 x 19 kW air blast, 2 x 30 kW roller bearing, 2 x 6 kW remoistening unit); 2 x 6 kW power supply paper reel transport system; 2 x 91 kW power supply cooling centre
Products	Commercial printing, e.g. advertising supplements, weekly papers
Printing carrier	Web printing papers with an average weight of ca 60 g/m^2.
Printing ink	Heat set ink (steam pressure < 0.01 kPa at 20°C; VOC potential: 35%, mineral oil components volatile in the dryer: 90 % of all mineral oil components, consequently ca 30% of the employed ink quantity. Average ink application per page: ca 1.2 g/m^2
Damping solution	Water (max. 10 °dH[4]), 8% isopropanol (100% VOC), 3% other damping solution additives(VOC concentration < 6%)
Dryer	2 x direct combustion (natural gas), temperature (paper web exit): 120°-140°C, exhaust gas volume flow ca 7,200 Nm^3/h (at 13 m/s production run), ventilator: 72 kW
Flue gas treatment	1 x regenerative thermal oxidation (thermo reactor), combustion chamber ca 900°C, VOC destruction efficiency: 99%, purified gas exit temperature ca 140°C; heat recovery: 93% thermal efficiency. Heating up with 2,100 kW gas, normal operation 2x700 kW gas 2x 200 kW electricity demand(ventilators): electricity consumption1,900 kW/a, auxiliary combustion ca 15 kW gas (at 13 m/s; 1.2 g/m^2 ink per page)
Cleaning agents	20 % roller-/blanket wash for cleaning by hand (100% VOC; steam pressure 0.05 kPa at 20°C) and 80 % blanket wash for wash-up device (0% VOC; steam pressure < 0.01 kPa at 20°C), reusable solvent cloths (40 gr. dry weight/item)

[ÖKOPOL 2002]

[4] 1°dH is equivalent to 10 mg/l CaO or 17.86 mg/l $CaCO_3$

2.5.2 Specific consumption and emission values (main processes)

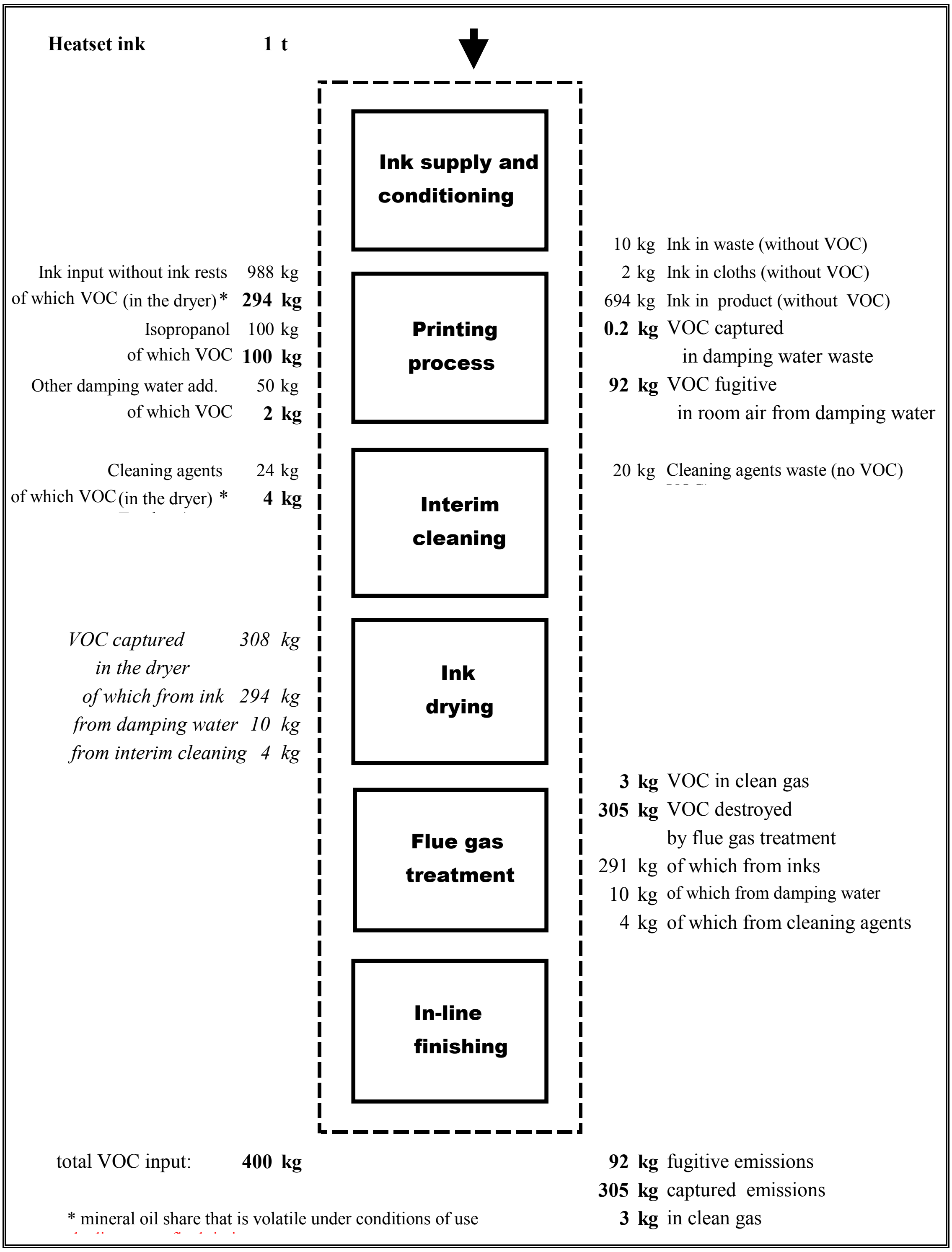
For the described printing plant the following specific consumption and emission values result at a progressive state of the art. As bigger printing plants are usually composed of several printing units, which are similar to the model plant, the specific values can be transferred to them.

The specific consumption and emission values are significantly dependent on the manufactured products. They increase with:

- decreasing print volume,
- rising employment of special colours (or change of colour sequence),
- extremely high demands on the printing quality (or difficult printing images),
- decreasing paper quality.

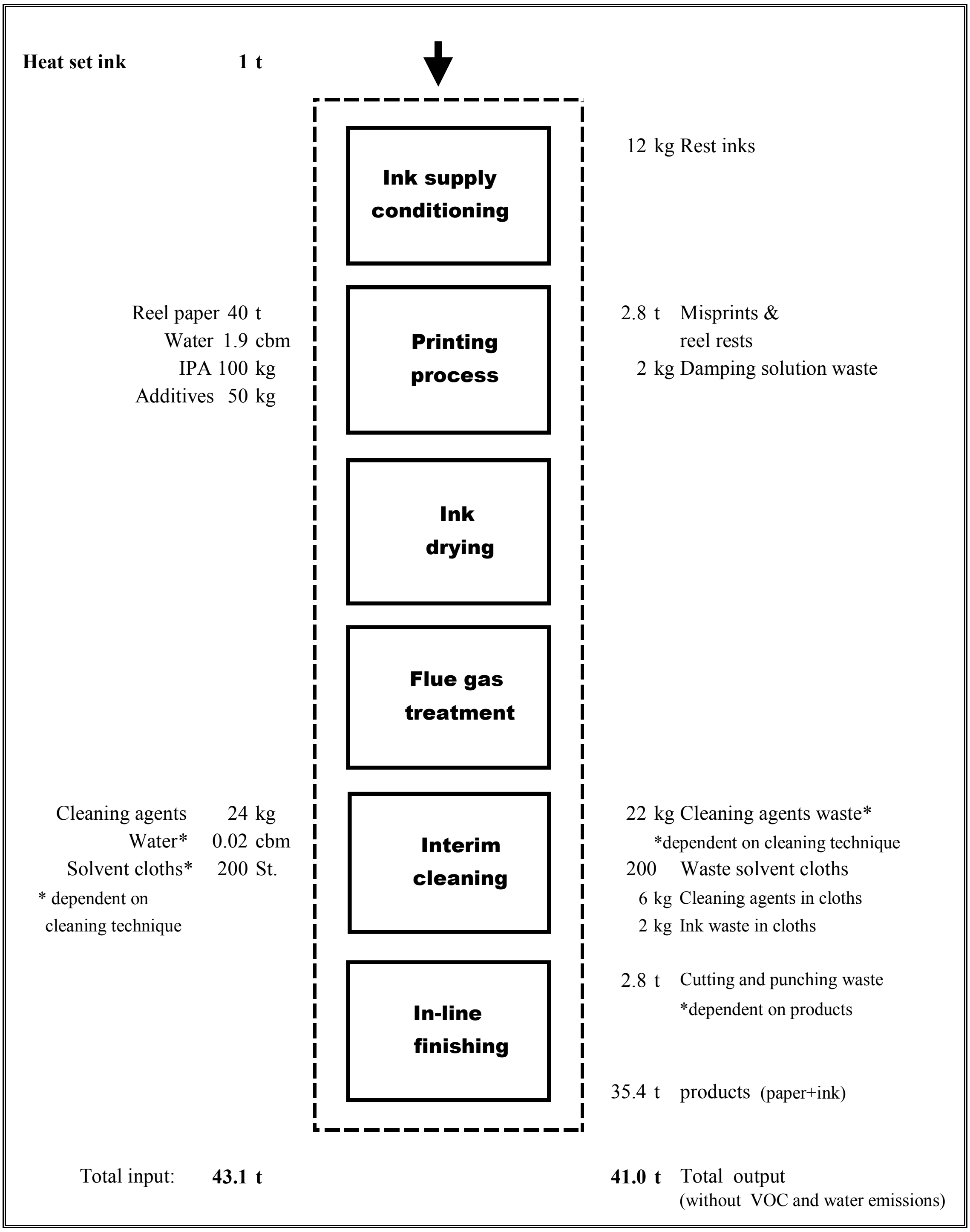
The stated values are average values, which can – dependent on the named parameters – vary in practice by ca +/- 10%.

Fig. 3: Specific VOC consumption and emissions (average values)



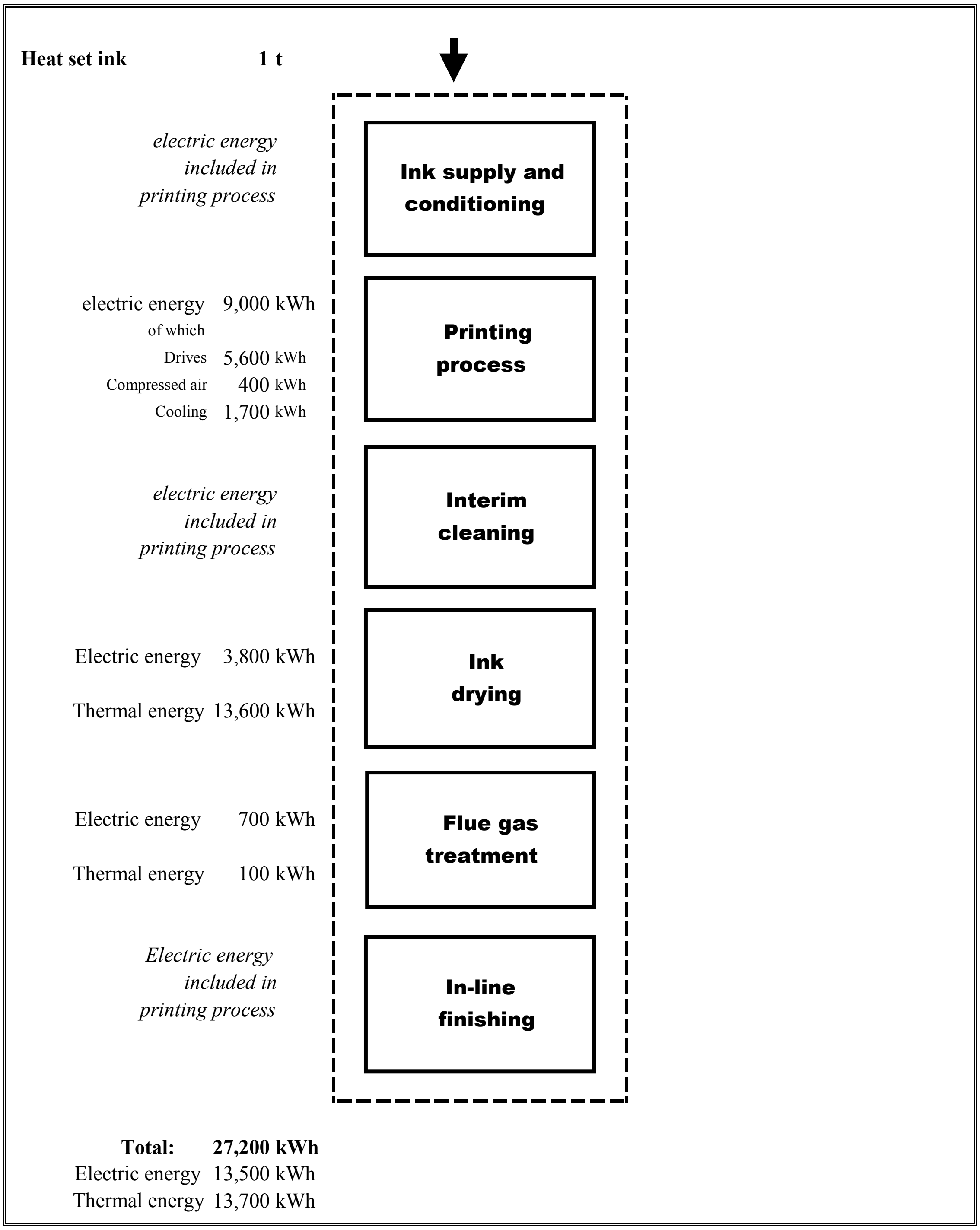
[ÖKOPOL 2002]

Fig. 4: Specific input of substances and output of waste (average values)



[ÖKOPOL 2002]

Fig. 5: Specific energy consumption (average values)



[ÖKOPOL 2002]

2.5.3 Reference plant

Tab. 10: Conditions of production

Production	3 shifts on 5.5 weekdays, 280 working days * 24h = 6,700 yearly working hours; ca 30% preparation and servicing time, ca 70% production => 4,700 production hours of the printing presses
Products	Ca 20,000 t/a papers with ca 500 t/a printing inks
Damping solution	950 m^3/a containing ca 50 t/a isopropanol and ca 25 t/a other damping solution additives
Cleaning	ca 15 t/a (80% for interim cleaning, 20% for basic cleaning, 100%) and ca 100,000 solvent cloths

Tab. 11: Yearly input/output balance

INPUT	**Amount**	**Unit**	**Explanatory notes**	**OUTPUT**	**Amount**	**Unit**	**Explanatory notes**
				PRODUCTS			
				Commercial printings	18,000	t/a	Paper and ink
MATERIAL				**WASTE**			
Printing carrier	20,000	t/a		Waste paper/misprints	2,800	t/a	
Printing inks	500	t/a	Mineral oil concentration in ink 35%, of which 85% volatile in the dryer (=30% of ink input).	Ink rests	6	t/a	Ink waste and in solvent cloths, no VOC
Damping solution	950	t/a	without VOC				
Isopropanol	50	t/a	100% VOC	Damping solution rests	2	t/a	VOC concentration 4%
Damping solution additives	25	t/a	5% VOC concentration (1 t VOC/a)				
Cleaning agents	15	t/a	80% VOC-free for interim cleaning, 20% for basic cleaning	Mixture of cleaning agents and water	23	t/a	Solvent concentration 50% (no VOC, high boiling substances)
Solvent cloths	100,000	items/a	Usually reusable cloths, weight ca 40 g/item	Solvent cloths	100,000	items/a	Loaded by 1 t printing ink and ca 3 t cleaning agents with 100% VOC, 50% of which evaporate fugitively (1,5 t)
VOC total	*203*	*t/a*		VOC in waste	2	t/a	in cloths, cleaning agents and damping solution waste
ENERGY				**EXHAUST GAS**			
Energy in total	27,100	MWh/a		Volume flow	67,700,000	m3/a	19 mg VOC/m^3
Gas energy	13,700	MWh/a		VOC in purified gas	1.3	t/a	
Electric energy	13,400	MWh/a		NO_x in purified gas	2.7	t/a	40 mg NOx/m^3
Of which : Printing press	*8,900*	*MWh/a*		CO in purified gas	3.4	t/a	50 mg CO/m^3
Cooling	*1,700*	*MWh/a*		**Fugitive**			
Flue gas treatment	*700*	*MWh/a*		VOC fugitive	47	t/a	

[ÖKOPOL 2002]

Tab. 12: Waste key values of the reference plant

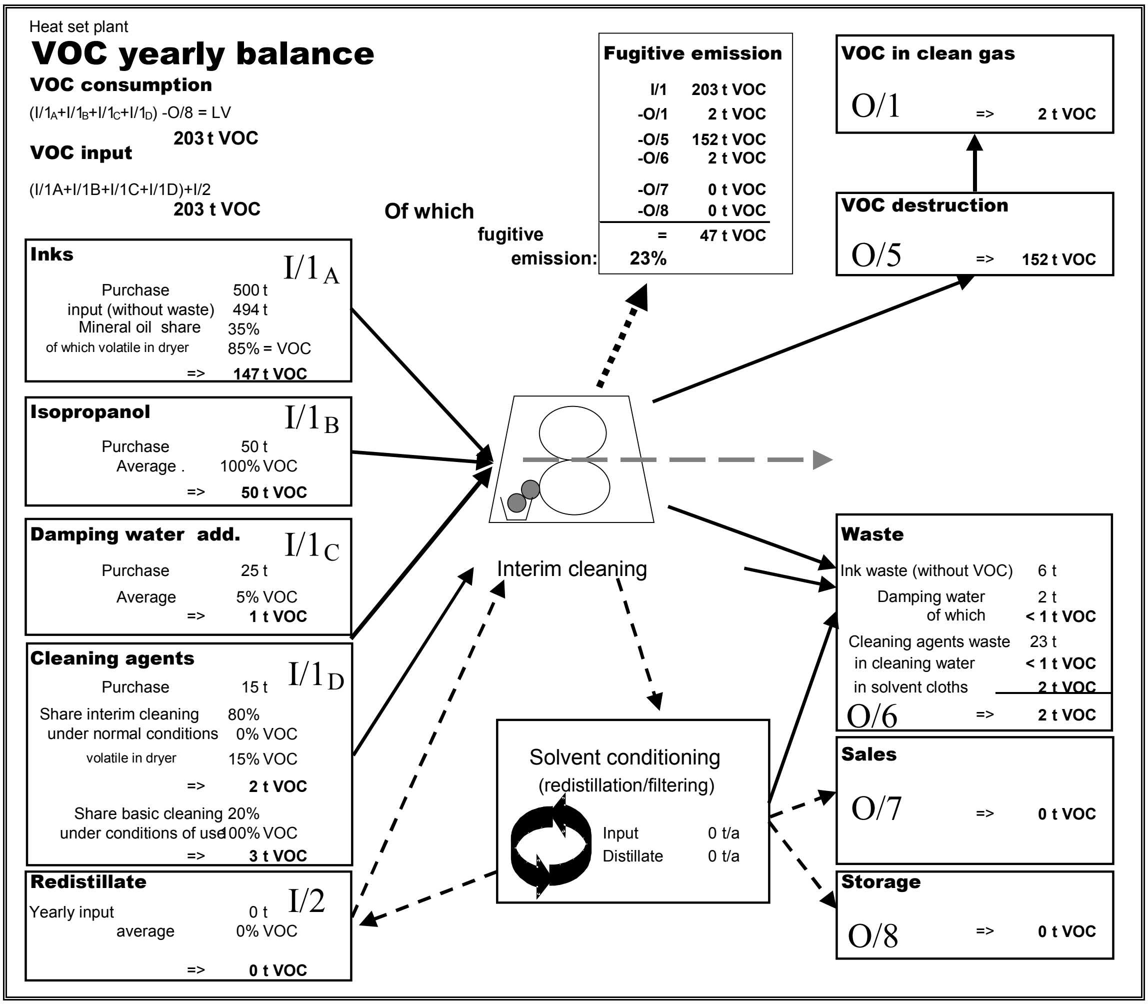
Pre-press stages		**Printing/finishing**	
Printing plate waste (dependent on print volume)	ca 0.04 – 0.09 t / t ink input	Paper waste	ca 10 – 20 %
Decoater waste	ca 0.1 – 0.2 l / m^2 printing plate	Ink waste	ca 1 – 3 %
Rinsing water	ca 5 – 15 l / m^2 printing plate	Damping solution waste	ca 0.002 m^3 / t ink input
		Number of solvent cloths	ca 200 items/ t ink input
		Solvent cloths contamination	10 g ink / item, 30 g cleaning agents / item
		Cleaning agents waste	No average values possible

[ÖKOPOL 2002; ÖKOPOL/ B.A.U.M. 1997]

VOC emission balance

For the described reference plant the VOC balance is presented in the illustration below.

Fig. 6: VOC balance of the reference plant



[ÖKOPOL 2002]

The balance shows that this plant meets the standards of the EU Solvent Directive. The reference plant represents an up-to-date heatset web printing plant.

2.6 BAT candidates

2.6.1 Summary

The following table lists – ordered by process steps – appropriate BAT candidates for heatset web offset printing plants.

Tab. 13: BAT candidates heatset web offset printing

No.	Measure	Process	Goal
BAT goal	**Reduction of VOC input for cleaning to < 5% of the ink input**		
H-1	Cleaning by high-boiling substances	Printing (interim cleaning), Basic and parts cleaning	Reduction of VOC input, Reduction of VOC air emission
	High boiling hydrocarbons (VOC-free) are used for cleaning work. Only few technical adaptations and a change of handling are necessary.		
H-2	Improved handling of cleaning	Printing (interim cleaning), Basic and parts cleaning	Reduction of VOC input, Reduction of VOC air emission
	By diligent handling (closed storage containers, economical use of chemicals, ...) of VOC containing substances(for the cleaning of not easily accessible machine parts) fugitive emissions can be avoided to a great extent.		
H-3	Blanket wash-up devices	Printing (interim cleaning)	Reduction of VOC input, Reduction of VOC air emission
	The blanket cylinders are equipped with automatic wash-up devices. This way the consumption of cleaning agents can significantly be reduced in comparison with hand cleaning.		
BAT goal	**Reduction of isopropanol concentration to < 8% (respectively < 10% of ink input)**		
H-4	Change to waterless offset printing	Printing (damping solution system)	Reduction of VOC input, Reduction of water input, Reduction of VOC air emission, Reduction of water emission
	Special printing plates are used which make it possible to work without damping solution. Additionally a temperature control (cooling) unit for the inking units must be installed. The printing quality is at least as good as the one of conventional printing. Price and durability of the printing plates are limiting factors at present		
H-5	Reduction of IPA	Printing (damping solution system)	Reduction of VOC input, Reduction of VOC air emission
	A reduction of the IPA concentration to 8-10% is feasible for most of the plants without additional technical measures. However, more diligence is necessary for the adjustment of the printing press .		
H-6	IPA measurement and dosage (continuously by infrared or ultrasound)	Printing (damping solution system)	Reduction of VOC input, Reduction of VOC air emission
	An exact and continuous measurement of the IPA concentration can be assured by new measurement systems. This is a condition of reproducible printing conditions at a reduced IPA concentration.		

No.	Measure	Process	Goal
H-7a	IPA substitutes	Printing (damping solution system)	Reduction of VOC input, Reduction of VOC air emission
	In order to reduce the IPA concentration the damping solution is added substitutes that replace parts of the functions of isopropanol.		
H-7b	Special hydrophilic rollers	Printing (damping solution system)	Reduction of VOC input, Reduction of VOC air emission
	Specially coated rollers guarantee even at a reduced IPA concentration a consistent wetting of the rollers of the damping system and subsequently an exact dosage of the water transport.		
H-7c	Combination of IPA substitutes and special hydrophilic rollers	Printing (damping solution system)	Reduction of VOC input, Reduction of VOC air emission
	(See above)		
H-7d	Water conditioning as a supplement of the measurements 150-7a to 150-7c	Printing (damping solution system)	Reduction of VOC input, Reduction of VOC air emission
	An exact adjustment of the water hardness and the pH value is guaranteed by a permanently monitored dosage of additives.		
BAT goal	**Reduction of the generation of ink rests to < 1% of the purchased ink**		
H-8	Automatic ink supply for frequently used inks and varnishes	Printing (damping solution system)	Reduction of waste
	The printing inks are piped out of reusable containers to the inking system. Pouring/decanting processes which lead to the generation of waste do not take place.		
BAT goal	**Reduction of the total energy demand**		
H-9a	Flue gas treatment (regenerative)	Flue gas treatment	Reduction of energy consumption
	Utilisation of the thermal energy of the outgoing air for the warming up of the crude gas by alternating heat transfer beds		
H-9b	Flue gas treatment integrated in the dryer	Dryer, flue gas treatment	Reduction of energy consumption
	Integration of the flue gas scrubber into the dryers is a very efficient way to use waste heat and to adjust the plant.		

[ÖKOPOL 2002]

2.6.2 Assessment of the BAT candidates

The following table presents a short assessment of the mentioned BAT candidates.

Tab. 14: Assessment of BAT candidates for heatset web offset printing

No.	**Measure**	**A**	**B**	**C**	**E**	**R**	**Additional costs**	**Obstacles**
H-1	Use of high boiling substances for cleaning	**↓**	↑	↑	-	-	Self-funding – high for old plants	Training and motivation of employees
H-2	Improved handling of cleaning	**↓**	-	-	-	**↓**	Cost-saving	Motivation of employees
H-3	Employment of blanket washers	**↓**	-	-	↑	↓	Cost-saving by time saving	Capital expenditure
H-4	Switch to waterless offset printing	**↓**	**↓**	↓	↑	↓	High (for old plants)	Capital expenditure, training of employees, monopoly of printing plate manufacturers
H-5	Reduction of isopropanol	**↓**	-	-	-	↓	Cost-saving	Training and motivation of employees
H-6	Measurement and dosage of IPA (continuously by infrared or ultrasound)	**↓**	-	-	-	↓	Self-funding- low (for old plants)	Capital expenditure, training and motivation of employees
H-7a	IPA substitutes	**↓**	↑	-	-	-	Self-funding	Training and motivation of employees
H-7b	IPA reduction by special hydrophilic rollers	**↓**	-	-	-	-	high (for old plants)	Capital expenditure, training of employees
H-7c	Combination of IPA substitutes and special hydrophilic rollers	**↓**	↑	-	-	-	low– high (for old plants)	Capital expenditure, Training and motivation of employees
H-7d	Water conditioning as a supplement of the measures H-7a to H-7c	**↓**	-	↑	↑	-	low– high (for old plants)	Capital expenditure, training and motivation of employees
H-8	Automatic ink supply for frequently used inks	-	-	**↓**	-	**↓**	Self-funding- low (for old plants)	Capital expenditure
H-9a	Flue gas treatment regenerative	-	-	-	**↓**	↓	high (for old plants)	Capital expenditure
H-9b	Flue gas treatment integrated in the dryer	-	-	-	**↓**	↓	high (for old plants)	Capital expenditure

Legend: A = Air pollutants and pollutant quantity, B= Water consumption and effluent charge ,
C =Amount and contamination of waste, E = Energy consumption, R = Consumption of resources

The dominating results are stressed by bold types. Considering this prioritisation there is a clear result of total assessment – even in case of opposite impacts in different environmental media.

2.6.3 New progressive processes

Tab. 15: Future BAT candidates heatset web offset printing

No.	Measure	Process	Environmental impact
BAT goal	**Reduction of energy demand**		
H-10	Flue gas treatment with waste heat recovery of the exhaust gas for the dryer	Dryer, flue gas treatment	Reduction of energy consumption, Reduction of air emission
	The thermal energy of the outgoing air and the waste heat of the flue gas treatment are used to warm up the crude gas and to heat up the dryer.		

Tab. 16: Assessment of the future BAT candidates for heatset web offset printing

No.	Measure	A	B	C	E	R	Additional costs	Obstacles
H-10	Flue gas treatment with waste heat recovery out of the exhaust gas and use of waste heat in the dryer	↓	-	-	↓	-	Self-funding – partly high (for old plants)	Capital expenditure

3. Package printing plants

3.1 Printing inks

3.1.1 Ink systems

In solvent-based package printing ethanol and ethyl acetate are the most common solvents. Furthermore flexo printing plants use isopropanol, n-propanol, methoxy propanol and ethoxy propanol. In gravure solvents like methyl ethyl ketone, i-propyl-acetate and n-propyl-acetate are applied.

The following table presents an average composition of a basic receipt.

Tab. 17: Average basic receipt for solvent-based package printing inks

Component	Contents	Concentration (wt.-%)
Binding agent		
- Solvent component	Normal-drying solvents: e. g. ethanol, n-propanol, isopropanol	60 - 70%
	Fast-drying solvents : e.g. ethyl acetate, i- and n-propyl acetate, MEK, naphthas	
	Slow-drying solvents : e. g. methoxy propanol, ethoxy propanol	
- Binding agent component	Cellulose derivates (e. g. nitro-cellulose) , polyvinyl butyrals, PVC, polyamides	10 - 20%
Colorants	inorganic pigments, organic pigments	10 - 15%
Colour auxiliary agents	e. g. softeners, waxes, slide agents	1 - 6%
Physical properties: Solids content: 25 - 40%; net calorific value: > 20 MJ/kg; flash point < 21°C		

The water concentrations in delivered printing inks stand at 50 - 60%. As binding agents mainly aqueous dispersions (e. g. of the type styrene-acrylate copolymer) are used. According to the purpose and the desired resistances acid resins, which are transformed into a water-soluble form by saponification with alkaline substances (ammonia or amines) are employed for modification. During the drying process the amines or ammonia escape, and the binding agent resins become insoluble in water again.

As drying additives are added the alcohols ethanol and isopropanol in low concentrations of mostly significantly below 5% [5]. The dilution can be made with water. In most cases the receipts contain additives like anti-foam agents, wetting agents and biocides.

5 In case of very special demands to the drying velocity , e. g. on thin papers, this percentage can rise up to 25 %.

Tab. 18: Average basis receipt for water-based package printing inks

Components	Contents	Concentration (wt-%)
Binding agent components		
- Aqueous solvent component	Water	50 - 75%
- Organic solvent component	Alcohols (e. g. ethanol, isopropanol)	0 -10%
- Other binding agents components	e.g. dispersion, acid resins	10 - 20%
Colorants	Inorganic pigments, organic pigments	10 - 20%
Colour auxiliary agents	e.g. waxes, softeners, complex formers	1 - 3%
	Saponification agents	1 - 5%
Physical properties: Solids content: 25 - 40%; net calorific value: < 10 MJ/kg; ca pH value 8		

For washing and cleaning primarily solvents are used which are – as solvent component - part of the inks. Plants employing water-based ink systems are in most cases cleaned by water, partly with admixtures of alkaline substances and tensides. Also mixtures of water with water-mixable organic solvents are used. In order to remove dried inks organic solvents are employed.

3.1.2 Typical ink covering

The applied amount of ink results from the product of ink application (ink quantity /printed surface) and area covering (printed surface/printing material surface), added from all printing units of the machine.

Ink application depends above all on the ink type. The following table presents some average values.

Tab. 19: Average ink application values

Colours	**Ink application (dry)** (for theoretical complete coverage]
White	1,5 – 2,0 g/m^2
True colours- coloured	1,0 – 1,5 g/m^2
Screen tint coloured	0,5 – 1,0 g/m^2

The mentioned values are only slightly influenced by the printing method or by the printing material.[6]

The area covering is determined by the printed image. It often stands only at 10 – 30%, even for striking colours, because of the effect of colour on the eye. The following table shows typical area coverings reached in practice.

6 In packaging gravure higher percentages of thinners than in flexo printing are necessary for the printing process .

Tab. 20: Typical area covering

Product spectrum	**Total area covering** [part of the printable surface]
Products without flat tints	130 – 180 %
Products with flat tints	200 – 300 %

Values of particular productions can deviate significantly. For corrugated area coverings of <20% are usual, while for high-quality consumer goods (e. g. for chocolate packages) area coverings of >400 % are reached.

Decisive for the total area coverage are especially the so-called „flat tints“, which are printed out of several reasons:

- On printing materials which are difficult to moisten (e. g. on foils), as a first printing run partly a primer is applied as an adhesive agent.
- For improvement of the colours' effects as a first step transparent plastic or metal foils are printed flat white. Also on paper webs this kind of basic colouring is common .
- In order to improve the characteristics of the colour surface for some special standards (e. g. UV and abrasion resistance) in the finishing printing job full-surface varnishing is employed.

3.1.3 Operational areas of the different printing ink systems

The advantages of solvent-based inks are:

- Higher quality of the printing job
  Up to now especially on many non-polar printing materials (plastic- /metal foils) only solvent-based ink systems can realise specific resistances ,e. g. against abrasion, grease, hot seals and varnishes.
- Less stress for the printing material
  The evaporation energy of the solvents is significantly lower than that of water, so that lower dryer temperatures and smaller drying periods can be chosen. Besides thermal stress, especially for thin papers the question of unwanted changes of geometry by water assimilation of the web plays an important role.

Therefore main areas of solvent-based packaging gravure are compounds packages with overprint varnish and applications of aluminium-coated compound materials. Example products in solvent-based flexography are flexible, water-resistant packages for food and cosmetics. Also in the area of flexible food packages which must be resistant to seals or used for wet filled goods mainly solvent-based ink-systems are used.

The advantages of water-based inks lie above all in the fact that during ink drying only few emissions of organic solvents occur. As a consequence, on one hand the emission limits of occupational health can be met without additional efforts, on the other hand flue gas treatment is not necessary. Direct printing and pre-print of corrugated employ more or less exclusively water-based inks. Other application areas with a high share of water-based inks are: Paper sacks and bags, wallpapers, envelopes and data processing paper, hygiene and household papers like table napkins, gift wrapping paper, labels, aseptic packages like milk and beverages cartons, PE carrier bags and sacks as well as shrink films.

At present printing with water-based inks is mainly a possibility for absorbent, porous printing materials out of paper and carton. The high latent heat and evaporation figure, but also the high surface tension of water (bad wetting of many plastics) are limiting factors of further operational areas. Among the polyolefins mainly PE foils are printable. In order to achieve good printing results on other plastics like PP, PES and PS, in most cases very selective adaptations of the printing parameters are necessary, e. g. a decrease of the printing speed. This is also valid for printing aluminium foils and aluminium-coated plastic foils.

Up to now, the changeover to water-based ink systems for printing gold and silver inks is particularly problematic. In label printing there is not yet a water-based alternative for the application of fluorescent inks because the existing ink systems would not be heat-resistant during their later use in laser printers and photocopiers. New developments let expect that in this segment die steady admixture of fluorescent inks will succeed already during paper production, so that there will be no necessity of a flat printing.

As a summary one can say that in Germany the majority of products, which can be printed with water-based ink systems without technical restrictions, are manufactured in this process variant. Therefore solvent-based package printing and water-based package printing serve two mainly separate product segments.

In practice one can find in many cases mixed processes between water- and solvent-based ink systems as well. Mostly solvent-based primers[7] or solvent-based varnishes[8] are printed in a water-based production in order to guarantee the desired product properties.

[7] As a first, full-surface printing job

[8] As a last, full-surface printing job

3.2 Employment of VOC

3.2.1 VOC containing solvents and additives

The following tables present a choice of typical VOC-relevant employed substances and their fields of application in solvent-based and in water-based package printing.

Tab. 21: VOC employment in solvent-based package printing

Substance	Steam pressure	Purpose
Ethanol	5.9 kPa	Solvent in ink, siccative, cleaning agent
Isopropanol	4.3 kPa	Solvent in ink, cleaning agent
Ethyl acetate	9.2 kPa	Thinner, cleaning agent
Isopropyl acetate	6.1 kPa	Thinner
Methyl ethyl ketone (MEK)	10.5 kPa	Siccative
n-Butanol	1.2 kPa	Anti-drying additive
Methoxy propanol	1.1 kPa	Anti-drying additive
n-Propanol	2.5 kPa	Anti-drying additive
Ethoxy propanol	0.65 kPa	Anti-drying additive
Various esters		Softener (Improvement of flexibility and adhesion) in printing inks and printing aids

As already stated, also in water-based package printing apart from water small quantities of organic solvents are employed. The following table shows an overview of typical substances.

Tab. 22: VOC employment in water-based package printing

Substance	Steam pressure	Purpose
Ethanol	5.9 kPa	Solvent in ink, siccative, cleaning agent
Isopropanol	4.3 kPa	Solvent in ink, cleaning agent
n-Propanol	2.5 kPa	Solvent in ink
Special naphtha (A I)	4.0 – 8.5 kPa	Cleaning agent
White spirit (A II, A III)	0.15 – 1.0 kPa	Cleaning agent

Most of the specified substances are part of the substance class III of the German “TA-Luft”.

3.2.2 Specific consumption quantities

Apart from VOC in purchased printing inks further relevant VOC quantities are used in ink thinning (viscosity control) and for several cleaning jobs. Especially in the area of viscosity control gravure and flexography are different. The following table presents typical mean values of specific VOC employments.[9]

Tab. 23: Specific VOC employment in package printing

VOC concentration in:	Printing inks		Thinners		Cleaning agents		Total
VOC concentration / ink quantity	∅	min-max	∅	min-max	∅	min-max	∅
Gravure solvent-based	60%	(40–70%)	101%	(70- 120%)	17%		**178%**
Flexography solvent-based	60%	(45 – 75%)	81%	(50 – 95%)	14%		**155%**
Gravure water-based	5%	(0 – 20%)	2%	(0 – 5%)	10%	(0 – 15%)	**17%**
Flexography water-based	5%	(0 – 20%)	2%	(0 – 5%)	10%	(0 – 15%)	**17%**

[ÖKOPOL 1999]

A result is for example that in package flexography ca 155 kg VOC/kg printing ink is used in the production and auxiliary processes of the plant.

On-site solvent recovery, which reduces the consumed quantity in comparison to the ink input is usually only relevant in the field of cleaning agents. If recovery plants are used, one can assume that the solvent consumption quantities quoted in the area “cleaning agents“ are reduced by 50 %.

3.3 Process scheme and characteristic material flows

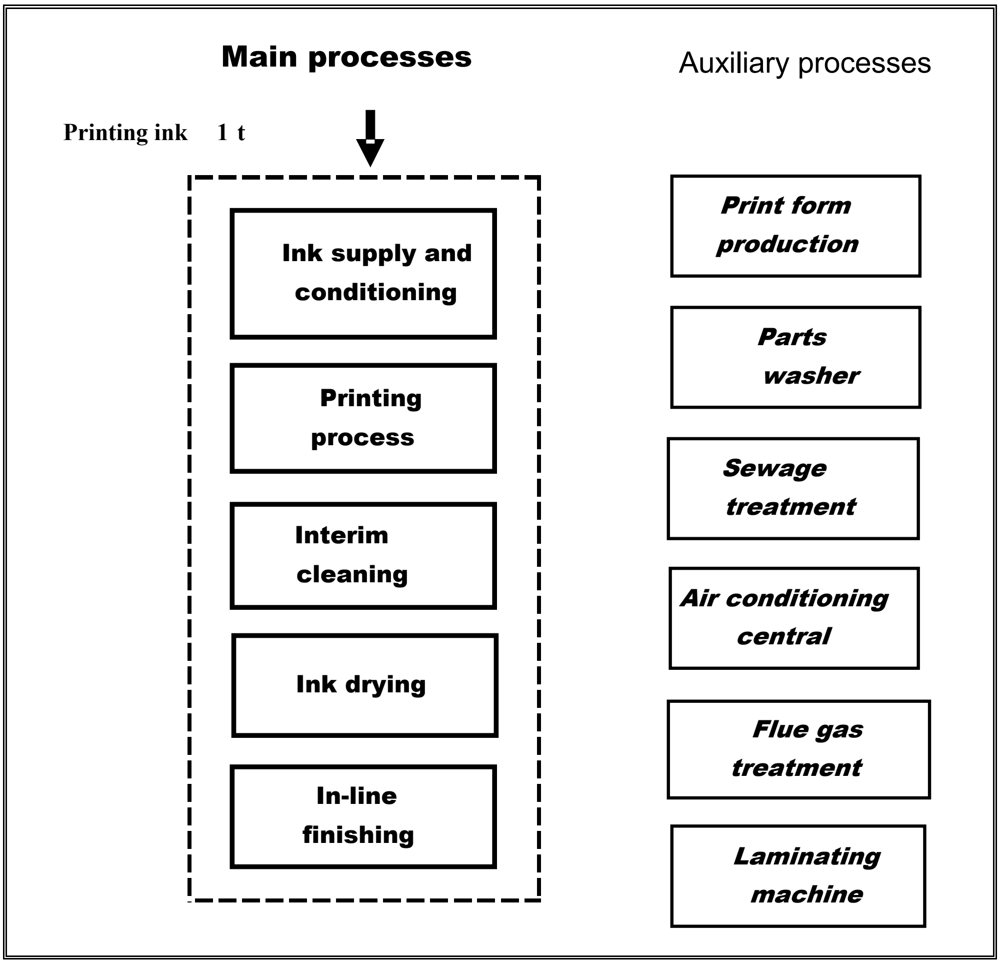
3.3.1 Scope of the BAT study

The variety of different possible process steps and combinations requires the fixing of system borders in order to achieve comparable BAT descriptions.

Comparable and reasonable consumption and emission values can be determined in direct relationship with the printing presses for the main processes shown in the following graphic. On the contrary it is more reasonable to describe the listed auxiliary processes as independent auxiliary plants.

9 The average values and spreads result from a branch study Ökopol carried out during the years 1997-99 in commission of the Federal Environmental Agency. The division of the total input of solvents into the areas of thinning and cleaning is regularly difficult in practice. While the total input of solvents is verified by a great number of intra-company data, the division into the separate processes is more or less an estimation.

Fig. 7: Main and auxiliary processes in package printing plants



3.3.2 Environmental impacts of the processes in a package printing plant

According to the scheme presented above the essential production processes of package printing will be described shortly and central environmental impacts will be listed. As in package printing all manufacturing processes are VOC relevant, the essential operational areas and emission sources of VOC are treated in this presentation.

Tab. 24: Environmental impacts in the main processes of a heatset plant

Process step	Environ-mental medium	Rele-vance	Explanations
Ink supply	Emissions	++	Fugitive VOC emissions from thinners and printing inks, quantity depends on handling and technical equipment (seal of solvent containers)
	Waste	+	5-15 % ink rests by ageing; especially for special colours: non-returnable metal containers
	Waste water	-	
	Energy	-	
Printing process	Emissions	+	Fugitive VOC emissions out of colour original containers and the interim dryers, quantity depends on handling and technical equipment (encapsulation)
	Waste	+	Start-up waste and misprints because of defects; quantity de-pends on the product, often 10% of the printed volume
	Waste water	-	
	Energy	+	Rising electricity demand esp. by increasing automation with compressed air demand and by direct drive; rising cooling de-mand because of increasing machine velocities
Interim cleaning	Emissions	+	Fugitive VOC emissions; quantity depends on handling
	Waste	+	Dirty solvent cloths, quantity depends on handling
	Waste water	-	
	Energy	-	
Ink drying	Emissions	+	Fugitive VOC emissions by blast air losses from the interim dry-ers For water-based inks 0,5 -1,0 % ammonia emissions/ink input
	Waste	-	
	Waste water	-	
	Energy	+	Dependent on dimensioning and regulation of the dryer
Finishing	Emissions	(+)	Partly fine dust out of the folder; dependent on paper quality Fugitive VOC emissions from „in-line gluing processes“, quantity depends on the product and the adhesive
	Waste	(+)	Cutting and punching waste, mostly small quantities; dependent on products
	Waste water	-	
	Energy	-	

Tab. 25: Environmental impacts in the auxiliary processes of a heatset plant

Process step	Environ-mental medium	Rele-vance	Explanations
Printing form production	*Emissions*	*(+)*	*Fugitive VOC emissions, in modern plants < 0,1 l/m^2 printing block surface*
	Waste	*(+)*	
	Waste water	*(+)*	
	Energy	*-*	
Indoor air conditioning	Emissions	-	
	Waste	-	
	Waste water	(+)	Low quantities of rinsing water from dampening plants and air conditioning
	Energy	+	Dependent on construction and energy concept
Parts cleaning	Emissions	+	Fugitive VOC emissions dependent on the employed agents and their handling
	Waste	+	Dependent on cleaning technique: dirty solvent cloths, mixtures of water and solvent , ink sludge
	Waste water	+	Only for water-based inks: ca 2-3 m^3/t ink, waste water with ca 15 g AOX/l, 20 mg Cu/l as well as 1-5 g hydrocarbons/l.
	Energy	-	
Recovery of cleaning agents	Emissions	-	
	Waste	(+)	Ink sludge, but lower quantities than without recovery
	Waste water	+	In case of solvent/water mixtures contaminated water phases (high COD, AOX and Cu values)
	Energy	(+)	Low demand in modern plants
Flue gas treatment	Emissions	(+)	Modern plants are sure to meet standards of <50 g/m^3 total C in the purified gas
	Waste	-	
	Waste water	-	
	Energy	(+)	Dependent on driving style and dimensioning of the plant (under optimum conditions mainly authothermic running with energy recovery possible)
Sewage treatment	Emissions	-	
	Waste	+	Ink sludge, quantities significantly higher in case of coagulation and flocculation
	Waste water	+	Ca 2-3 m^3/t ink, with outlet concentrations < 1 AOX mg/l, < 200 mg COD/l, < 10 mg hydrocarbons/l
	Energy	(+)	Dependent on the plant concept

3.4 Up-to-date consumption and emission values

3.4.1 Model plants

A flexography central impression cylinder plant of an average production width, as it is used in a great number of package printing companies, serves as model plant.

Tab. 26: Basic data of the package printing model plant

Machines	Flexography central impression cylinder plant; 8 inking units, format 127 x 100 cm, web velocity up to ca 250 m/min
Dryer	Indirect heating of interim dryer and bridge dryer by heat transfer oil, circulating air technique controlled via solvent concentration
Finishing	Reel slitter, cross cutter, rewinder

[ÖKOPOL 2002]

3.4.2 Specific consumption and emission values (main processes)

For the main processes in the mentioned printing plant the specific consumption and emission values resulting at a progressive state of the art are described in the following. Because large printing plants are usually composed of several of the described printing units, which are similar to the model plant, the specific values can be transferred to larger plants.

In order to draw an objective picture of the range of consumption and emission values achieved in practice, two different driving styles of the model plant are described. On one hand a production with generally solvent-based inks, on the other hand a mixed production with water-based inks and a solvent-based cover varnish.

The following table presents the determined product parameters and conditions of production.

Tab. 27: Conditions of production of the reference package printing plant

Conditions of production	280 production days/a, 3 shifts; 6,525 operating hours/a with 70% production printing time => 4,560 production printing hours /a
Products	Paper wrappers 70 gr/m2 Solvent-based:: 6 colours, area coverage 155%, ink application 4,98 gr/m^2, web velocity: 150 m/min Mixed process 6 colours + cover varnish, area coverage 255%, ink application 4.9 gr/m^2 + cover varnish 2.5 gr/m^2, web velocity 150 m/min
Finishing	Slitting and rewinder

The IPPC solvent consumption limits (>200t $_{VOC}$/a) are reached already by one printing press in a generally solvent-based production while in mixed production 2-3 printing presses are necessary.

The following tables show average specific consumption and emission factors. They increase with:

- Decreasing print volume,
- Increasing number of change of colour sequence
- Particularly high demands on the printing quality (or difficult printed images)
- Decreasing paper quality.

The specific values for material and energy consumption related to the ink input naturally are especially dependent on the average ink coverage (g/ m$^{2)}$.
For a production by gravure the admixture of thinners (VOC input) and the corresponding VOC emissions out of ink supply would be 10 – 20% higher.

Considering the mentioned dependence the given values are average values, which can vary in practice by +/- 20%.

Tab. 28: Specific VOC consumption and emission values (solvent-based process)

1,000 kg printing ink containing 500 kg VOC		
731 kg thinner (100% VOC)	**Ink conditioning**	
	Printing process	160 kg fugitive VOC losses
70 kg cleaning agent (100% VOC)	**Interim cleaning**	45 kg fugitive VOC losses
	Ink drying	1,063 kg VOC in the outgoing air to FGT (6.80 g/m^3 in 133,100 Nm^3 outgoing air)
	Finishing	
TOTAL input: **1,301 kg VOC Input**		**TOTAL output:** 205 kg fugitive VOC losses 1,060 kg VOC destruction in FGT ca 2-3 kg VOC in purified gas ca 33 kg VOC in waste

Tab. 29: Specific energy consumption (solvent-based process)

1,000 kg printing ink		
(included in the printing process)	**Ink conditioning**	
3,185 kWh el. drives 1,010 kWh el. cooling 580 kWh el. compressed air	**Printing process**	
(included in the printing process)	**Interim cleaning**	
2,800 kWh thermal oil (ca 51% out of inter-station dryers/ 49 % out of bridge dryer) 985 kWh el. fans	**Ink drying**	
(included in the printing process)	**Finishing**	
350 kWh el. fans *- 5,785 kWh therm. (energy recovery)*	***Flue gas treatment***	
TOTAL input: **6,110 kWh el.** **- 2,985 kWh therm.**		

Tab. 30: Specific consumption of substances and generation of waste

1,000 kg printing ink		
731 kg thinner	**Ink conditioning**	
21,875 kg paper	**Printing process**	1,900 kg misprints 90 kg ink rests
120 solvent cloths	**Interim cleaning**	120 solvent cloths with: ca 1.4 kg ink rests + 3 kg solvents
	Ink drying	
	Finishing	*(misprints included in printing process)*
	Flue gas treatment	

The following tables present in the same way the specific consumptions and emissions for a combination of water-based inks and a solvent-based cover varnish.

Also in this case the specific consumption and emission values are influenced by the factors mentioned above. However there are further effects.

If the share of solvent-based ink systems rises, the VOC input and emissions increase while the sewage quantity and effluent charge decrease – and vice versa.

Tab. 31: Specific VOC consumption and emission values (mixed process)

1,000 kg printing ink containing **31 kg VOC**		
625 kg print varnish containing **156 kg VOC** **198 kg** thinner (100 % VOC)	**Ink conditioning**	
	Printing process	**58 kg** fugitive VOC losses
	Interim cleaning	
	Ink drying	**323 kg** VOC in outgoing air to FGT (1.38 g/m³ in 234,370 m³ outgoing air of 69°C)
	Finishing	
<u>**TOTAL input:**</u> **385 kg VOC input**		<u>**TOTAL output:**</u> **58 kg fugitive VOC losses** (15,0%) **320 kg VOC destruction** in FGT **ca 3 kg VOC in purified gas** ca **4 kg VOC in waste**

Tab. 32: Specific Energy consumption (mixed process)

1,000 kg printing ink		
(included in printing process)	**Ink conditioning**	
3,180 kWh electric drives 1,010 kWh electric cooling 580KWh electric compressed air	**Printing process**	
(included in printing process)	**Interim cleaning**	
5,500 kWh therm. (ca 42 % out of inter-station drying/ 58 % out of bridge dryer) 980 kWh el. fans	**Ink drying**	
(included in printing process)	**Finishing**	
1,300 kWh therm. 450 kWh el. fans	***Flue gas treatment***	
<u>**TOTAL input:**</u> **6,200 kWh el.** **6,800 kWh therm.**		

Tab. 33: Specific consumption of substances and generation of waste (mixed process)

1,000 kg printing ink		
516 kg water 625 kg print varnish 198 kg thinner	**Ink conditioning**	
21,875 kg paper	**Printing process**	1,900 kg misprints 140 kg ink rests
120 solvent cloths 1,200 l water	**Interim cleaning**	120 solvent cloths containing ca 1,4 kg ink rests 1,200 l sewage (containing ca 18 kg COD)
	Ink drying	
	Finishing	*(misprints included in printing process)*
	Flue gas treatment	

3.4.3 Reference plant

Short description of the reference plant

The reference plant produces 6 days a week in 3 shifts in 3 flexography central impression cylinder plants with a web width of 1.30 m. In two plants mainly generally solvent-based products are manufactured, while the third plant manufactures a relevant share (> 85%) of exclusively water-based or mixed products. With a yearly consumption of ca 500 t of VOC the consumption limit of the IPPC Directive is clearly exceeded.

The flexo printing blocks (printing forms) are purchased from specialised service providers. The printing products are winded up after printing and delivered as pre-products to brand-name article manufacturers. A finishing within the plant itself does not take place.

For air emission control a catalytic flue gas scrubber with heat recovery is installed. The outgoing air systems of the printing presses are equipped with circulating air technique controlled via solvent concentration.

For the treatment of the ink-contaminated process sewage (from interim and parts cleaning) a sewage treatment plant on the basis of ultrafiltration is installed.

For the cleaning of the inking unit an enclosed cleaning unit with integrated solvent recovery is used.

Consumption and emission values

Tab. 34: Yearly input/output balance of a package printing plant

Material	Amount Unit	Annotations	Products	Amount Unit	Annotations
Paper	10,433 t/a		Pre-products	9,700 t/a	
Printing inks	576 t/a	Of which ca. 1/4 water-based	Waste		
with VOC ca.	189 t/a		Misprints	740 t/a	
Thinner	316 t/a		Ink rests	41 t/a	with ca 10.8 t VOC
Water for cleaning & thinning	666 m³/a		Contaminated Solvent-(water) Mixtures	15 t/a	with ca. 9.8 t VOC
Water for cooling & air conditioning	51,866 m³/a		Process sewage	545 m³/a	
Cloths	144,100 items/a		Cloths	144,100 items/a	with ca. 2.5 t VOC
Energy			**Waste air**		
Energy el	3,320 MWh/a		FGT-waste air	72,450,000 m³/a	
Energy therm.	350 MWh/a		VOC from FGT	1.38 t/a	
			NOx from FGT	4.70 t/a	
			CO from FGT	2.72 t/a	
VOC balance values					
VOC total input	505 t/a		VOC fugitive	96 t/a	ca. 19% of the input
			VOC destroyed	384 t/a	
			VOC clean gas	1,4 t/a	
			VOC waste	23 t/a	

[ÖKOPOL branch database, 2002]

When comparing the consumption and emission values of the reference plant with the specific ones of the model plants one must note that in this case all auxiliary processes with their additional consumptions and emissions are recorded.

VOC balance:

The standards of the EC Solvent Directive are met as Tab. 34 shows; especially those standards concerning the emission limits for fugitive emissions (≤ 20%). Important factors for this quite good emission situation are the supply of the inking units with thinner by pipes, a frame air extraction as well as the supply of exhaust gas from the parts cleaner to the flue gas treatment.

3.5 BAT candidates

3.5.1 Summary

The following table lists – ordered by process steps – appropriate BAT candidates for solvent based (sb) and water based (wb) package printing plants.

Tab. 35: BAT candidates for package printing plants

No.	Use	Measure	Process step	Reduction effect
BAT goal	**Reduction of fugitive VOC emissions to < 18 %**			
VD-1	sb, wb	Enclosed ink mixing units	Ink conditioning	Reduction of VOC emissions Reduction of ink rest generation Reduction of container waste
		By using enclosed and automatically controlled ink mixing units special colours are mixed according to the demand, and the VOC emissions from thinners (viscosity control) are minimized.		
VD-2	sb, wb	Diligent handling of inks and solvents	Ink conditioning Printing	Reduction of VOC emissions Reduction of ink rest generation
		By guaranteeing a well-sealed condition of all solvent containers , a diligent and economical use of these agents and the prevention of the contamination of rest inks significant reductions of consumption and emission can be achieved.		
VD-3	sb	Addition of thinner in pipes	Ink conditioning	Reduction of fugitive VOC emissions
		Solvents for viscosity controlling are piped directly to the inking units. VOC emissions out of storage containers are reduced.		
VD-4	sb	Improved enclosure of inking units and dryers	Printing Drying	Reduction of fugitive VOC emissions Reduction of energy consumption of the FGT
		By an improved enclosure and extraction of the printing plants (especially in the area of inking units and interim dryers) the efficiency of the FGT increases and the fugitive VOC emissions decrease.		
VD-5	sb	Use of automatic wash-up devices	Machine cleaning	Reduced consumption of cleaning agents Reduction of fugitive VOC emissions
		The use of automatic ink unit wash-up devices reduces the consumption of solvents for the interim cleaning and helps avoid fugitive VOC emissions		
VD-10	sb	Connection of parts washing places to FGT	Basic and parts cleaning	Reduction of fugitive VOC emissions
		The extraction of VOC emissions from parts washing places (and parts washers) and their supply to FGT helps avoid fugitive VOC emissions.		
VD-7	sb	Enclosed parts washers with integrated recovery	Parts cleaning	Reduced consumption of cleaning agents Reduction of solvent waste Reduction of fugitive VOC emissions
		Enclosed wash-up devices reduce the fugitive VOC emissions from parts cleaning, by an integrated solvent recovery the consumption of chemicals and the quantity of waste can be significantly reduced.		

No.	Use	Measure	Process step	Reduction effect
BAT goal	**Reduction of energy consumption**			
VD-8	sb, wb	Optimised control engineering of the dryers (concentration)	Ink drying	Lower energy consumption of the dryers Optimised operation of the FGT
		The circulating of parts of the outgoing air controlled via solvent concentration reduces the crude air quantity of the FGT and increases its VOC load.		
VD-9	sb	Optimised design of the flue gas treatment	Flue gas treatment	Lower energy consumption of the FGT
		Optimisation of the FGT for average manufacturing conditions ensures that the FGT can be run as often and long as possible in the optimal operating range.		
BAT goal	**Reduction of waste quantities**			
VD-11	wb	Ultrafiltration as sewage treatment, possibly with ink recovery	Sewage treatment	Reduction of waste quantities Reduction of ink consumption
		By the use of (ultra-) filtration units the generation of hazardous waste from using auxiliary agents can be avoided. There is also the possibility to re-use the recycled ink sludge as printing ink: If mixed waste water is captured ,as an additive to black colours, if waste water is captured separately from inking units of different colours the colours can be re-used separately.		
VD-6	sb, wb	Employment of reusable solvent cloths	Machine cleaning Parts cleaning	Reduction of material consumption Reduction of waste
		The employment of reusable solvent cloths reduces the waste to be disposed of and leads to a more diligent handling of these materials.		

The BAT candidates make sense or in a solvent based (sb) and/or in a water based (wb) type of process as determined in the column titeled “use”. The VOC consumption limits of the EC IPPC Directive are usually only exceeded in a solvent based and in a mixed production as well water based as solvent based inks. In the table above mixed plant runs are also enclosed by “wb“.

In all views of BAT it is assumed that every package printing plant, which exceeds the consumption capacity limits of the EC IPPC Directive, is equipped with a flue gas treatment.

Fig. 8: VOC input and emission sources in a typical non-BAT package printing plant

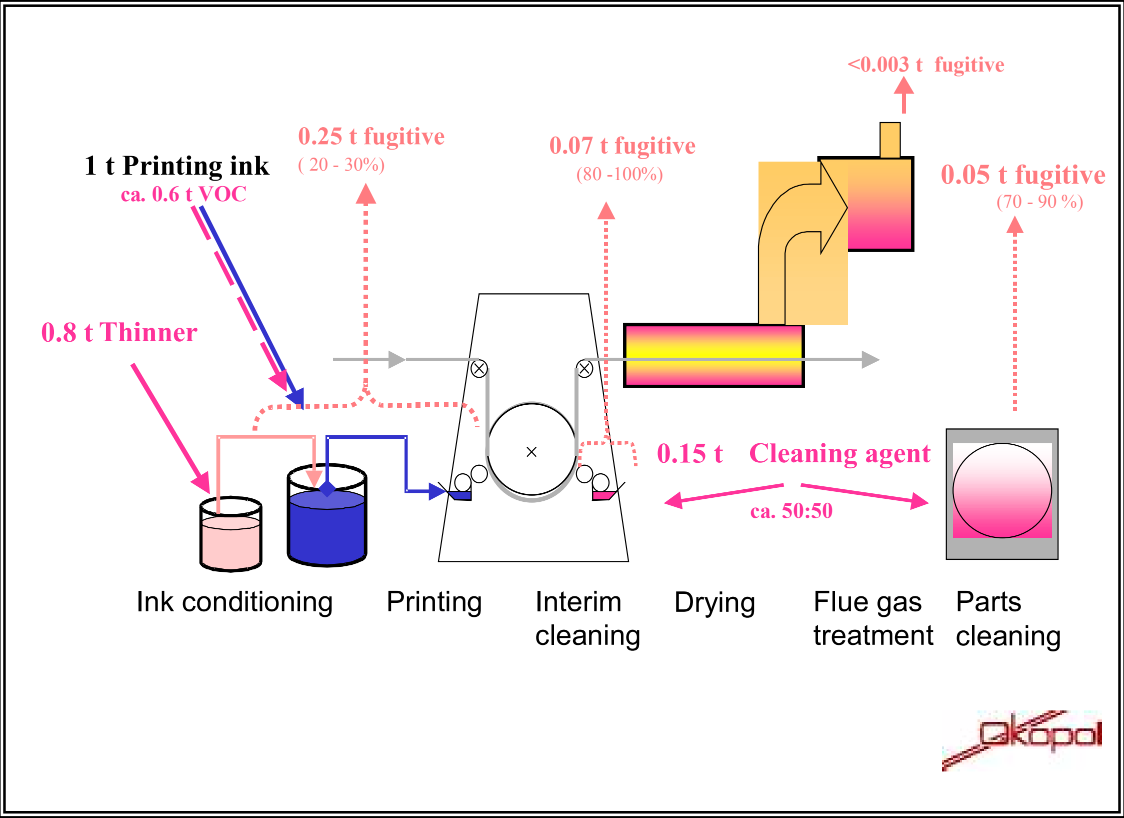
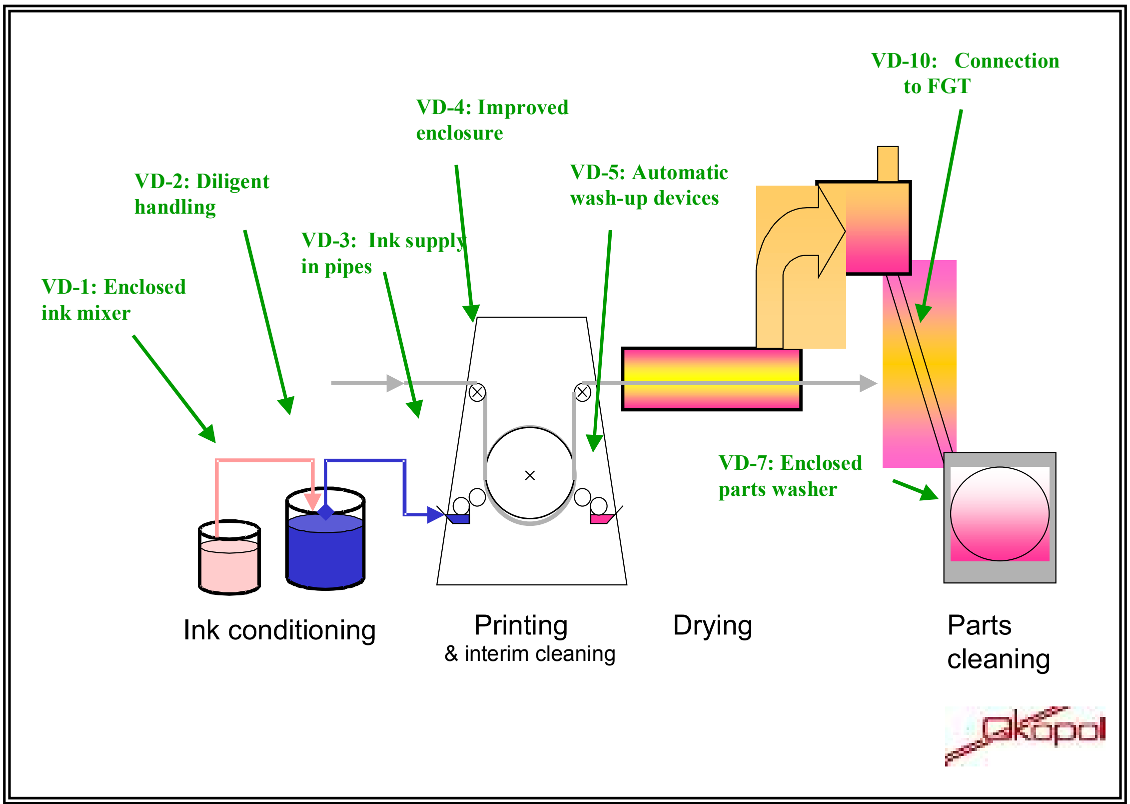


Fig. 9: Attempts of the mentioned BAT candidates for the reduction of fugitive VOC emissions



3.5.2 Assessment of the BAT candidates

The following table shows a short assessment of the described BAT candidates.

Tab. 36: Assessment of the BAT candidates for package printing plants

No.	Measure	A	B	C	E	R	Additional costs	Obstacles
VD-1	Enclosed ink mixing units	↓	-	**↓**	-	↓	Medium	Only available for high ink consumption and a limited number of qualities
VD-2	Diligent handling of inks and solvents	**↓**	-	↓	-	↓	Self-funding	Motivation of employees
VD-3	Addition of thinners in pipes	**↓**	-	-	-	-	Low for new plants	None - trend for new plants
VD-4	Better enclosure of inking unit and dryer	**↓**	-	-	↑	-	Low for new plants	Technically complicated for old plants, handling takes time
VD-5	Use of automatic wash-up devices	**↓**	-	-	-	-	Low for new plants	None - trend for new plants
VD-6	Employment of reusable solvent cloths	-	-	**↓**	-	↓	Self-funding	None
VD-7	Enclosed parts washers with integrated recovery	**↓**	-	↑	-	-	Medium	None
VD-8	Optimised control engineering of the dryers (concentration)	↑	-	-	**↓**	-	Medium for new plants	Dependent on architectural conditions
VD-9	Optimised design of the flue gas treatment	↓	-	-	**↓**	-	Low– high (for old plants)	Technical difficulties in a number of old plants
VD-10	Connection of parts washing places to FGT	**↓**	-	-	↑	-	Medium- high (for old plants)	Dependent on architectural conditions
VD-11	Ultrafiltration as sewage treatment, possibly with ink recovery	-	-	**↓**	-	-	Low - self-funding	Ink recovery depends on the ink colours

Legend: A = Air pollutants and pollutant quantity, B = Water consumption and effluent charge,
C = Waste quantity and waste contamination, E =Energy consumption , R = Consumption of resources

The dominating impacts are stressed by bold types. In compliance with this assessment there are obvious results of the total environmental impact even in case of opposite impact on the different parts of the environment.

3.5.3 New progressive processes

Tab. 37: Future BAT candidates package printing

No.	Use	Measure	Process	Effect on the environment
BAT goal		**Reduction of energy consumption**		
VD-A	sb, wb	Switch to UV printing inks	Ink conditioning & printing	Reduction of solvent consumption Reduction of VOC emissions
		The changeover to UV printing inks avoids VOC emissions out of ink conditioning and ink drying		
VD-B	sb	Use of parts cleaners operating with lyes	Parts cleaning	Reduction of VOC emissions
		The use of cleaning agents containing lyes in parts washers avoids VOC emissions in this area		
VD-C	sb	Use of less volatile cleaning agents	Interim cleaning	Reduction of VOC emissions
		The use of less volatile cleaning agents (high-boiling hydrocarbons) helps avoid VOC emissions from the interim cleaning		
VD-D	sb, wb	Complete switch to water-based inks for mixed products	Ink conditioning & printing	Reduction of VOC emissions
		Water-based inks that guarantee all demanded „resistances " of the package production would make it possible to do without solvent-based inks (especially primers and cover varnishes).		

Tab. 38: Assessment of future BAT candidates for package printing

No.	Measure	A	B	C	E	R	Additional costs	Obstacles
VD-A	Switch to UV printing inks	↓	-	-	↑	-	Investments; operating costs dependent on the development of the market	Partly problems because of odour, printing problems for some special colours esp. in gravure, specific costs higher at the moment but dependent on market development
VD-B	Use of parts washers operating with lyes	↓	-	↑	-	-	Investment in new wash-up devices necessary, costs for auxiliary agents higher at present, in some cases higher waste disposal costs	Might cause damage to the material, on-site recycling not possible
VD-C	Use of less volatile cleaning agents	↓	-	↑	-	-	Higher specific costs for cleaning agents (dependent of market development)	Different and very diligent handling necessary in order to avoid printing problems, partly problems with damage to the material
VD-D	Complete switch to water-based inks for mixed products	↓	-	-	↑	-	None to low	Up to now water-based ink systems are not available for all fields of application

4. Illustration gravure

4.1 Printing inks

Because of its high machine velocity, illustration gravure makes high demands on ink drying . Thus only colours with a high concentration of the volatile solvent toluene are used. The drying process is always physical no matter which material is printed. The solvent component evaporates, while the evaporation process is accelerated by heat supply (hot-air dryers/heated paper web guide). As a binding agent hard resins, partly ethyl cellulose are used. The following table shows an average basic receipt for illustration gravure.

Tab. 39: Average basic receipt of illustration gravure ink

Component	Contents	Concentration (wt.-%)
Binding agent - Solvent component - Binding agent component	 Toluene e. g.: phenol resins, hydrocarbon resins, ethyl cellulose	 50 - 60% 30 - 40%
Colorants	organic, inorganic pigments (mainly process colours)	8 - 20%
Colour auxiliary agents	e. g. waxes, dispersants, defoamers	1 - 4%
Physical properties: Solids content 35 - 55%; net calorific value >20 MJ/kg; flash point < 21 °C		

In the printing plant inks of the above receipt are significantly thinned before being printed. The toluene concentration in the press-ready ink lies at ca 70 – 80 wt.-%.

4.2 Employment of VOC

Tab. 40: VOC relevant substances in illustration gravure

Substance	**Steam pressure** [at 20°C]	**Specific input** [in wt.-% of the ink input]	**Purpose**
Toluene	2.9 kPa	54,7%	Solvent in ink and gravure varnish
		100,0%	Thinner in the printing process
		31,8%	Cleaning agent (for different cleaning jobs)
Ethanol	5.9 kPa	<< 1%	Siccative for cylinder correction
Turpentine substitute	0.04 kPa	<< 1%	Cleaning agent for cylinder correction
Acetone	24.0 kPa	<< 1%	Cleaning agent for cylinder correction

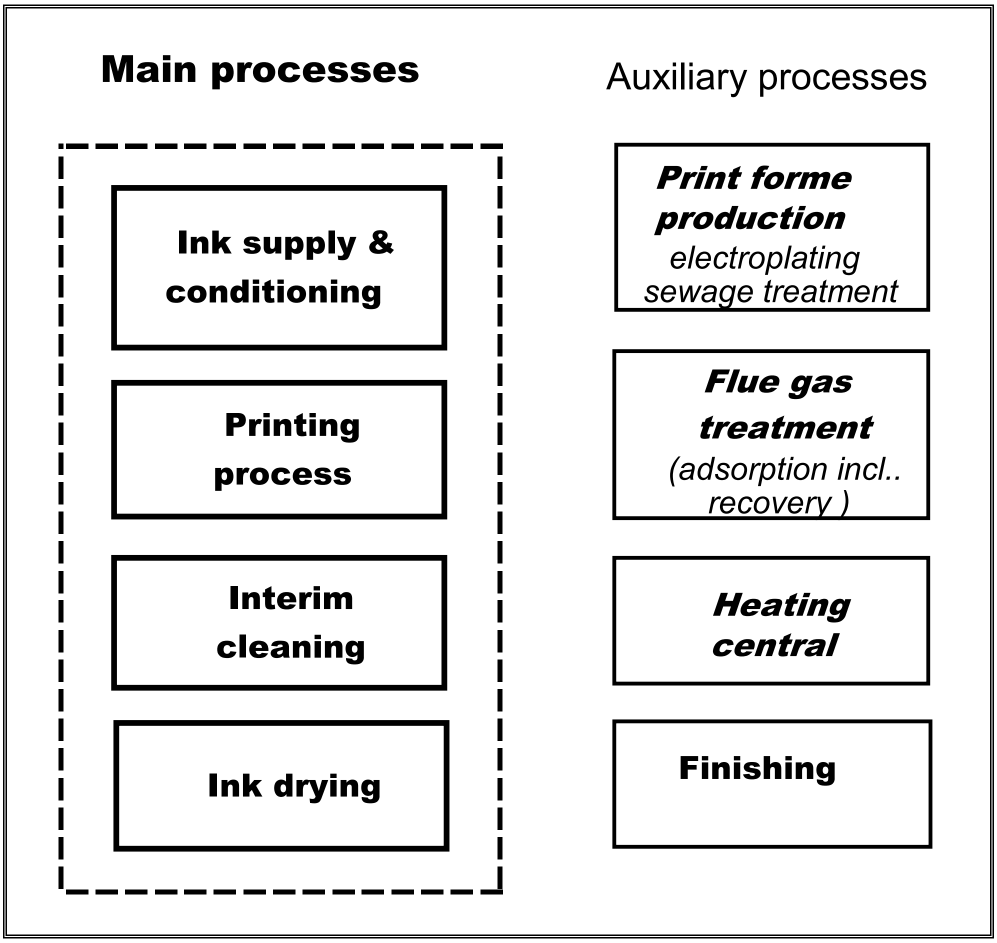
[ÖKOPOL 1999]

4.3 Process scheme and characteristic material flows

4.3.1 Scope of the BAT study

The following scheme presents an overview of the relevant manufacturing processes of an illustration gravure plant:

Fig. 10: Manufacturing processes in an illustration gravure plant



4.4 Up-to-date consumption and emission values

4.4.1 Reference plant

Tab. 41: Yearly input/output balance of an illustration gravure plant

INPUT				**OUTPUT**			
	Amount	Unit	Annotations		Amount	Unit	Annotations
Pre-products				**PRODUCTS**			
Purchase	3,100	t/a		Pre-products	86,366.77	t/a	
MATERIAL				**WASTE**			
Printing material	91,300.00	t/a		Waste pa-per/misprints	8,005.20	t/a	
Printing inks	2,210.20	t/a	Including gravure varnish	Ink-/varnish rests	15.69	t/a	Hazardous
Water	158,150.00	m3/a	Well water	Galvanic sludge	7.5	t/a	Hazardous
Of which:	123,100.50	m3/a	Cooling water	Activated carbon	2.6	a/a	Out of adsorbers
	9,000. 00	m3/a	Electroplating				
	6,500.00	m3/a	Heating				
Cloths	600,125.00	Items/a	Reusable cloths, number of washings				
Energy				**EXHAUST GAS**			
Energy total	67,509.20	MWh/a		VOC from FGT	7.23	t/a	Ø 35 mg C / m^3
Energy gas	44,050.70	MWh/a		NOx from energy central	7.58	t/a	Energy central using natural gas
Energy electricity	24,010.50	MWh/a	Of which 5,618 MWh/a air conditioning 7,179 MWh/a printing presses	CO from energy central	0.18	t/a	Energy central using natural gas
				VOC fugitive	364.88	t/a	
				sewage			
				total	33,200	m3/a	Of which 2.418 m3/a electroplating

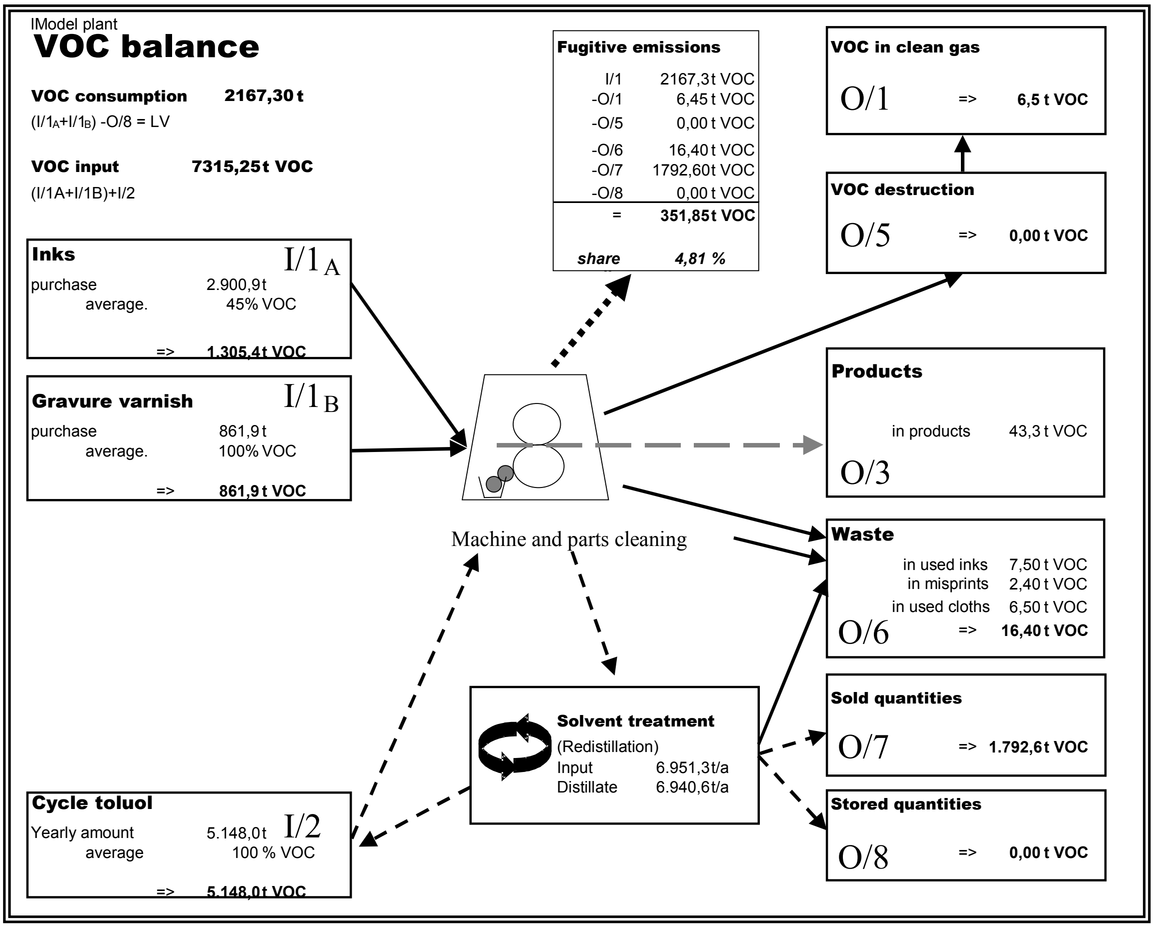
[ÖKOPOL 2002]

The reference plant described above is a modern illustration gravure plant which produces in 5 gravure plants - containing in total 40 ink units - mainly magazines and partly catalogues of high quality and circulation.

VOC balance:

Employing emission factors that are typical for the branch, the following VOC balance results for the model plant described above.

Fig. 11: VOC balance of the illustration gravure model plant



The plant remains significantly below the emission limits of the EC Solvent Directive (total C in captured exhaust gas ≤ 75 mg C/m^3; share of fugitive emissions ≤ 10 % of the VOC input).

The reference plant is equipped with the BAT candidates IT-1 to IT-5.

4.5 BAT candidates

4.5.1 Summary

The following table lists – ordered by process steps – appropriate BAT candidates for illustration gravure plants.

Tab. 42: BAT candidates for illustration gravure plants

No.	Measure	Process step	Reduction effect
BAT goal	**Reduction of the total VOC emissions to< 5% of the Toluene input**		
IT-1	Use of rest toluene reducing printing inks	Ink conditioning & printing	Reduction of fugitive VOC emissions
	In „rest toluene reducing inks" skinning on the ink surface is delayed by a modified receipt. So a higher percentage of the toluene contained in printing ink can be expelled directly in the ink drying unit of the printing plant. The remaining charge of products in the delivery of the machine can be reduced by 30-50% that way.		
IT-2	Air extraction at collecting places of ink rests and solvent cloths	Printing & interim cleaning	Reduction of fugitive VOC emissions
	Contaminated cloths and ink rests are stored at special collecting places with a separate air extraction so that VOC emissions are captured by the flue gas treatment		
IT-3	Basic cleaning by dry ice in-stead of solvents	Basic cleaning	Reduction of fugitive VOC emissions
	Dried ink is removed during maintenance and basic cleaning work by blasting with dry ice pellets. This way VOC emissions are completely avoided.		
IT-4	Continuous monitoring of the adsorber performance	Flue gas treatment	Reduction of captured VOC emissions
	In order to prevent breakthroughs of crude gas modern metrology and control engineering is used.		
IT-5	Supply of the adsorber drying air to the FGT	Flue gas treatment	Reduction of captured VOC emissions
	In order to avoid toluene emissions, the outgoing air of the adsorber (during the drying process after desorption) is supplied by special air canals again to the intake air of the flue gas scrubber		
BAT goal	**Optimisation of the total energy demand**		
IT-6	Installation of circulating air technique	Ink drying & flue gas treatment	Reduction of VOC emissions Reduction of energy consumption
	The outgoing air of the flue gas scrubber is directly used as intake air for the press enclosure. Emis-sions of clean gas are avoided and parts of the thermal energy can be recovered.		

4.5.2 Assessment of BAT candidates

The following table shows a short assessment of the described BAT candidates.

Tab. 43: Assessment of BAT candidates for illustration gravure

No.	Measure	A	B	C	E	R	Additional costs	Obstacles
IT-1	Use of rest toluene reducing printing inks	↓	-	-	-	↓	None or low	Restrictions for special colours
IT-2	Air extraction at collecting places for ink rests and solvent cloths	↓	-	-	-	↓	None or low	Partly architectural restrictions
IT-3	Basic cleaning by dry ice instead of solvents	↓	-	-	-	-	none	Experience necessary
IT-4	Continuous monitoring of the adsorber performance	↓	-	-	-	-	low	
IT-5	Supply of the adsorber drying air to FGT	↓	-	-	↑	-	Dependent on FGT concept; mainly low	In old plants partly architectural restrictions
IT-6	Installation of circulating air technique	↓↑	-	-	↓↑	-	Dependent on conditions of the plant and its site	Modification technically complicated for old plants
Legend: A = Air pollutants and pollutant quantity, B = Water consumption and effluent charge, C = Waste quantity and contamination, E = Energy consumption, R = Consumption of resources								

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