SOLVENT BASED OR WATER BORNE INKS IN FLEXOGRAPHY

A COST COMPARISON

A study for Johnson Polymer

FINAL REPORT

Sitmae Consultancy BV
Paul W.Verspoor MBA
February 2005

TABLE OF CONTENTS

ANNEXES

1. EXECUTIVE SUMMARY

1.1 The study

The purpose of this study was to identify and where possible quantify the differences in cost between the application of solvent based and water borne inks. The study was limited to recently developed water borne inks, suitable for printing on PE for the production of heavy duty bags, bread bags, packaging for frozen foods and similar products. With regard printing speed, production efficiency, product quality etc, there is no difference between those inks and their solvent based equivalent.

This study was performed from a printer’s perspective. Wherever savings or increases in the printers’ cost due to water borne inks were not certain, a conservative approach was taken; always conservative from the printer’s point of view.

Detailed cost budgets of flexography plant and interviews with both printing executives and their suppliers, have been used to identify all the items that might be influenced by the introduction of water borne inks. All cost calculations have been based upon real life situations. The literature that was used for this study is listed in Annex 3.

1.2 Conclusion

Continued use of solvent based ink is more expensive than application of waterborne inks, by at least 20 to 35% of the annual ink and solvent cost; where 20%, or 280.000 € per year, applies to large plant with an annual ink consumption of 250 tons and 25%, or 85.000 € per year, applies to small plant with an annual ink consumption of some 40 tons.

This difference is mainly caused by two advantages of water borne inks that reinforce each other:

- Avoidance of high environmental cost associated with continued use of solvent based inks
- Lower per m² price of water borne inks

Avoiding environmental cost

In the coming few year three environmental EU directives will affect flexography plant simultaneously, since their latest implementation dates almost coincide. These directives are:

- Solvent Emissions Directive (SED)
- Integrated Pollution Prevention and Control Directive (IPPC)
- Protection of Workers from Explosive Atmospheres Directive (ATEX).

The cost for compliance with these directives is considerable and may be avoided by the application of water borne inks.

Where solvent based inks are continued to be used, the need to comply with this legislation will raise total cost with at least 11 to 27% of the annual ink and solvent cost, where 11% applies to large plant with an annual ink consumption of 250 tons and 27% applies to small plant with an annual ink consumption of some 40 tons. These cost increases can be fully prevented by the application of water borne inks.

To reap this advantage, it is in most EU Member States enough to apply of 75 to 80% water borne inks and other solvent free products. Considering the conservative approach taken in the calculations, the actual cost increases that can be avoided with water borne inks, may very well exceed those presented here.

Lower per m² price

The per m² price of water borne inks is substantially lower than that of solvent based inks, even where the per kg price may be up to 20% higher. The savings more than offset the unavoidable cost necessary for successful introduction of water borne inks. The use of water borne inks not only prevents cost rises, it actually reduces cost by some 10% of the annual ink cost.

Green field sites

In the long term, additional savings will be made since new machinery and buildings or the renovation of existing assets will be substantially cheaper where water borne inks are used. This long term advantage is estimated to amount to some 10% of the annual ink and solvent cost. Green field sites will have this advantage immediately.

Partial substitution

Incineration of waste gasses is the most expensive part of the environmental cost that can be avoided by using water borne inks. However, in case less than 75 or 80% of waterborne inks is applied, incineration can generally not be avoided. In that a case the cost increases due to continued use of solvent based inks cannot be completely prevented by applying water borne inks. They can however still be reduced.

A 50% switch to water borne inks will, still reduce the cost increases by some 7 to 8% of the annual ink cost. In individual cases these saving may be much higher, since water borne inks may be applied on presses or in buildings where compliance with the new environmental legislation would be disproportionately expensive.

1.3 Model plant and relevant cost

In order to investigate and compare the differences in cost as transparently as possible, three theoretical model plant were designed*:*

Model plant	**Unit**	**Large**	**Medium**	**Small**
Economic figures				
Personnel	x	100	50	25
Turnover	million €	15.0	6.5	2.9
Added value	million €	8.6	3.9	1.8
Raw materials	k€	6,380	2,600	1,090
EBIT	k€	860	410	170
Production time				
Number of presses	No	4	3	2
Production time p.a.	hours p.a.	3,840	2,880	2,400
Solvent based inks				
Total ink bought, 36% solids	t/a	250	97	41
Solvent bought	t/a	245	104	48
Total cost solvent & ink	k€	**1,409**	**553**	**239**

For the sake of the cost comparisons, the most important parameter was found to be the volume of ink annually purchased. Other parameters, such as number of personnel or annual turnover, were far less relevant.

The following groups cost items were identified as relevant:

- Ink and associated cost: cost of ink and solvents, energy consumption in dryers, removal and treatment of waste
- Environment and safety: waste gas incineration, reduction and control of fugitive solvent emissions, waste water treatment, storage, application of Best Available Techniques, prevention of explosive atmospheres
- Other cost: anilox rollers, image carriers, tests, miscellaneous
- Management time: Introduction of water borne inks, quantification and reporting of fugitive emissions, drafting a reduction plan, annual solvent balances, complex environmental permit, explosion protection document, compliance with Occupational Exposure Limits.

1.4 Ink and associated costs

Where two different inks must have the same effect on a substrate, the amount of pigment per m² must be the same. A cost comparison between solvent based and water borne inks must therefore be based upon the amount of pigment. Other factors that have been taken into account are the solvents needed for dilution, the energy required for the drying process and the disposal and treatment of waste.

- Solvents generally add some 10 to 15% to the ink cost.
- Although the evaporation of water requires more energy than the evaporation of solvent, there are several factors that compensate for this effect, such as the much smaller volume of water and the absence of safety hazards; the difference in energy cost for dryers is negligible.
- Waste of water borne ink is filtered rather than distilled. The amount of sludge is larger. This increases the annual amount of waste to be disposed of. Also the caloric value of water borne sludge is lower. Where large quantities of waste need to be treated this increases the price.
- Per kg, water borne inks are more expensive than their solvent based equivalent, but they will cover a larger surface.

Even at a conservative estimate of a 20% higher per kg price, the net effect is a reduction of some 11 to 13% of the total ink and solvent cost. Water borne inks are some 161, 68 and 31.000 € per year cheaper for the large, medium and small model plant respectively.

1.5 Environmental cost

In the case of continued use of solvent based inks, incineration of waste gasses from dryers is necessary due to the Solvents Emissions Directive. The cost of incineration depends largely on the maximum dryer airflow: 80,000, 45,000 and 30,000 m³/h for the large, medium and small model plant respectively.

The total cost of incineration are some 140; 80 and 60,000 € per year for the large, medium and small model plant respectively, equivalent to 10, 15 and 25% of the annual ink and solvent cost

In the case of continued use of solvent based inks, the SED also demands reduction of fugitive emissions. Where however the incinerator, its ducting and its automatic operation are well designed, no additional cost needs to be incurred.

In the case of water borne inks, a waste water treatment system is generally necessary. Often an ultra filtration system technique is used. The operational cost is offset by the operational cost of distillation of used solvents. The additional capital cost of waste water treatment is some 4,800; 2,400 and 2,400 € per year for the large, medium and small model plant respectively. The cost of waste water treatment is but a few percent of the cost of incineration.

Additional environmental cost arises in the case of continued use of solvent based inks. This cost may be very high, but they vary too much from case to case for representative quantification:

- Medium sized and large plant will need a complex IPPC environmental permit. This permit will to prescribe the use of Best Available Techniques. In some European countries this will lead to an increase in cost. In other countries it will bring forward the moment of new and additional environmental investments. Especially the safe storage of solvents and solvent based inks may require early additional investment, since recently European standards have been published. Bringing an old storage room for flammable materials up to standard may easily cost € 100,000.
- The cost of compliance with ATEX (protection against explosive atmospheres) will also vary widely from plant to plant. In the worst cases an investment of well over € 100,000

may be necessary, in other cases the expense will be limited to going through the formality of making an adequate explosion protection document.

1.6 Other cost

The solid content of the water borne machine ready ink is substantially higher than that of solvent based inks. This means that a number of anilox rollers need to be replaced with rollers with a finer screen. An investment is necessary to replace these anilox roller sooner than otherwise would have been necessary.

Water borne inks also need different image carriers. In the case of repeat jobs these cost can not be billed to a customer. Water borne inks can however be introduced gradually, such that jobs are switched to water borne when the need for new plates arises anyway.

Test runs are necessary for successful introduction of water borne inks. These test runs do normally not replace any productive work. The cost for machines and operators are therefore negligible. The raw material cost for the test runs is however not.

For the sake of the calculations, the cost for tests and replacement of anilox rollers is amortised over a five year period.

The total 'other cost' for the introduction of water borne inks are some 15, 11 and 7,000 € per year for the large, medium and small model plant respectively, equivalent to 1, 2 and 3% of the annual ink and solvent cost.

1.7 Management time

Compliance with the new environmental requires management time and sometimes the use of consultants. However where water borne inks are used the issues are very much simplified and therefore less time consuming. On the other hand, management time is also needed for the successful introduction of water borne inks.

An estimation was made of the number of days necessary for two different of management levels and for consultants over a period of five years in which compliance with environmental legislation is sought. The amount of time necessary in the case of continued use of solvent based inks was estimated at some 125, 100 and 70 days for the large, medium and small model plant respectively. In the case of water borne inks the numbers were less than half in each case.

For the sake of the calculations a different daily 'fee' was allocated to the time spent by consultants, upper management and middle management. The total cost was amortised over a five year period in order to obtain annual costs. In the case of solvent based inks these annual cost were some 16, 12 and 9,000 € for the large, medium and small model plant respectively. In the case of water borne inks these cost were 7, 5 and 4,000 €.

1.8 Existing plant

The study focussed on short term effect in existing plant: existing presses in existing buildings. In the long term additional saving will be made. Green field plant reap these additional benefits immediately

To avoid most of the environmental cost associated with continued use of solvent based inks, a 75 to 80% switch to water borne inks is generally sufficient. This gives the flexibility to still use some solvent based inks, where unavoidable limitations of water borne inks must be circumvented, such as for instance printing gold and silver colours.

The results of the calculations for the model plant are:

Model plant		**Large**		**Medium**		**Small**	
Solvent based/water borne	**Unit**	**SB**	**WB**	**SB**	**WB**	**SB**	**WB**
Total ink and solvent cost	**k€/yr**	**1,409**	**1,248**	**554**	**486**	**240**	**208**
Ink & solvent: saving	k€/yr		- 153		- 65		- 30
Environmental Cost	k€/yr	138	2	82	1	58	1
Other cost	k€/yr		15		11		7
Management time	k€/yr	16	7	12	5	9	4
Total cost increase	**k€/yr**	**155**	**- 129**	**94**	**- 49**	**67**	**- 18**
Cost change, % of ink cost	**%**	**11%**	**-9%**	**17%**	**-9%**	**28%**	**-8%**
Total difference	***k€/yr, %***	***284***	***20%***	***143***	***26%***	***85***	***35%***

In the case of continued use of solvent based inks, environmental legislation will give rise to substantial cost increases: for the model plant at least 155,000; 94,000 and 67,000 € per year in the large, medium and small model plant respectively. This corresponds to 11 to 28% of the annual ink and solvent cost, where the 11% applies in case of an annual ink consumption of 250 tons and the 28% to an annual ink consumption of some 40 tons.

In real life, the cost increases for the use of solvent based inks may be substantially higher, since a number of items with a potential for further cost increases were not included in the model plant calculations.

In addition actual saving is incurred. The lower per m² price of water borne inks is substantial and more than offsets the unavoidable cost necessary for successful introduction of these inks. The saving for the model plant are at least 129,000; 49,000 an 18,000 € per year in the large, medium and small model plant respectively. This corresponds to 9 to 8% of the annual ink and solvent cost, where 9% applies in case of an annual ink consumption of 250 tons and the 8% to an annual ink consumption of some 40 tons.

In total the continued use of solvent based inks is substantially more expensive than application of water borne inks. The difference is at least 20 to 35% of the annual ink cost, where 20%, or 280,000 € per year, applies to large plant with an annual ink consumption of 250 tons and 25%, or 85,000 € per year, applies to small plant with an annual ink consumption of some 40 tons.

In practice the difference in cost is probably larger, because of the conservative approach taken in the calculations. These are based on a 20% per kg price difference between water borne and solvent based inks and environmental cost associated with the continued use of solvent based but unsuitable for the model plant approach were not counted.

1.9 Long term effect & green field plant

Throughout this report only cost increases and savings with a time horizon of but a few years have been taken into consideration. Looking further ahead however, water borne inks unavoidably lead to additional and potentially large savings whenever important changes in the flexography plant occur.

In order to estimate the potential for long term saving, green field plant was studied. A green field plant will immediately reap all the benefits that will come to the existing plant in the long term. The main differences are:

- Storage: No safe storage room of solvent based inks, no safe tanks for solvents
- Explosive atmospheres: No explosion free equipment, lighting, switches, motors etc in press room or on presses, no safety features on dryers, much reduced ventilation in the building
- Environment, Health & Safety: No solvent resistant floor, no local extraction, fewer partitions and fire doors in the building, resulting in a cheaper building and better logistics

It is estimated that the total investment in a green field plant would be some 10% lower if the use of solvents can be avoided. The annual depreciation figures for the three model plant are 900, 400 and 160,000 € respectively. The annual capital cost, including less loss of interest, in a green field site would be lower by some of 150; 60 or 25,000 € for the large, medium and small model plant. This means in general that applying water borne inks in a green field plant leads to savings on capital cost, additional to those for existing plant, of some 10% of the ink and solvent cost.

Since investment in new fixed assets or renovation of existing assets will be substantially cheaper where water borne inks are used, existing plant will in the long run also reach these lower cost.

1.10 Limited use of water borne inks

A 'limited use of water borne inks' means that so much solvent based ink remains, that incineration cannot be avoided. This obviously implies that the savings from a switch to water borne inks will be less significant; there is a need for both an incinerator and waste water treatment and management time will be necessary for both the environmental complexity of solvent based inks and for the introduction of water borne inks.

Model plant		**Large**		**Medium**		**Small**	
Solvent based	**Unit**	**100%**	**50%**	**100%**	**50%**	**100%**	**50%**
Total ink and solvent cost	**k€/yr**	**1,409**	**1,329**	**554**	**520**	**240**	**224**
Ink & solvent: saving	k€/yr		-76		-33		-15
Environmental Cost	k€/yr	138	1	82	1	43	1
Other cost	k€/yr		11		8		5
Management time	k€/yr	16	18	12	13	9	10
Total cost increase	**k€/yr**	155	-47	94	-11	52	1
Cost change, % of ink cost	**%**	**11%**	**-3%**	**17%**	**- 2%**	**22%**	**0%**
Potential savings		**8%**	**108**	**15%**	**82**	**22%**	**53**

From the cost items for which a reasonable estimation can be made, annual savings of can be expected of some 8 to 22% of the annual ink cost, where 8%, or 108,000 € per year, applies to large plant with an annual ink consumption of 250 tons and 22%, or 53,000 € per year, applies to small plant with an annual ink consumption of some 40 tons.

In real life the savings may however be much more substantial. Disproportionately high cost associated with continued use of solvent based inks on specific machines or in specific parts of the buildings may be avoided by applying water borne inks in these specific cases.

1.11 Decision tools

Two easy to use tools are added as annex 1 and 2 respectively:

- With the help of Annex 1: 'Is it possible to avoid incineration?' it can be determined whether the scope for application of water borne inks is large enough to avoid the need to install incineration equipment.
- With the help of Annex 2: 'Is it possible to avoid an IPPC permit?', it can be determined whether the scope for application of water borne inks is large enough to avoid the need for an environmental permit based upon the IPPC directive.

2. INTRODUCTION

2.1 Purpose of the study

Water borne inks in flexography are presently used for printing paper and, to a lesser extent, for the production of plastic carrier bags. Recent developments however allow the production of inks that are suitable for printing on PE for the production of heavy duty bags, bread bags, packaging for frozen foods and similar products. This study is focussed on the application of these recently developed inks.

In flexography, the use of solvent based inks gives rise costs that do not arise where water borne inks are used and vice versa.

In the case of solvent based inks the emission of solvent vapours to the environment needs to be prevented, personnel needs to be protected against high concentrations of solvent vapour and the flammability of solvent necessitates special storage requirements, the prevention of explosive atmospheres, the avoidance of possible ignition sources and a host of protective measures to be applied to buildings and machinery.

In the case of water borne inks on the other hand, the inks may be more expensive, waste water treatment may be necessary, dryers may use more energy and the switch over from solvent based to water borne inks may require tests and changes in equipment.

> The purpose of this study is to identify and where possible quantify the differences in cost between the application of solvent based and water borne inks.

2.2 Cumulation of new legal requirements

An important part of the cost comparison concerns a number of new legal requirements that are specific to the continued use of solvent based inks.

> In the coming years three important EU environmental directives will affect flexography plant almost simultaneously. The cost for compliance with this legislation is considerable and may be very much reduced by the application of water borne inks.

The three directives in question are:

Solvent Emissions Directive (SED): From October 2007, every flexography plant using over 15 tons of solvent per year will either need to install expensive incineration equipment or substitute some 75% of it's solvent based inks, varnishes and adhesives by solvent free or low solvent alternatives.

Integrated Pollution Prevention and Control Directive (IPPC): From October 2007, every flexography plant with a capacity to consume over 200 tons of solvent per year will need to have a comprehensive environmental permit and will need to apply 'Best Available Techniques' (BAT).

Protection of workers from Explosive Atmospheres (ATEX): From June 2006, every flexography plant will need to draw up an explosion protection document, assess and determine the explosion risks, classify the plant into explosion zones, take adequate measures and provide adequately safe equipment.

2.3 Printing speed & customer requirements

> This study is limited to the recently developed water borne inks mentioned earlier, suitable for printing on PE for the production of heavy duty bags, bread bags, packaging for frozen foods and similar products. With regard printing speed, production efficiency, product quality etc, there is no difference between these inks and their solvent based equivalent.

As in many other manufacturing industries, profitability in the flexible packaging industry is not high. A reasonable profit margin can only attained with very effective and efficient production processes. Presses need occupied for more than 80% of the available time, and must run at considerable speed without jeopardising customer requirements.

Where the use of new inks would lead to lower printing speeds or would make it impossible to meet customer requirements, profitability would immediately suffer; whatever the savings in cost would be.

2.4 Flexibility & partial switch over

As will be shown, one of the most important cost saving of water borne inks is the avoidance of incineration equipment for the waste gasses. It must be noted that this can already be achieved where some 75 to 80% of the solvent based inks are replaced by water borne inks. The European Solvent Emissions Directive explicitly equals such partial substitution of solvent based inks to the application of expensive abatement equipment.

This fact introduces an important amount of flexibility; it is possible to continue to use 20 to 25% solvent based inks, without losing the most important cost advantage of water borne inks. This will in some plant be most welcome to compensate for some unavoidable limitations in the applicability of water borne inks. It will for instance allow the continued production of speciality products with exceptional customer requirement.

> To enjoy all or most of the savings in cost associated with water borne inks, it is sufficient to attain a 75 to 80% switch over. This gives the flexibility to use solvent based inks where necessary to circumvent some unavoidable limitations of water borne inks.

Annex 1 of this report contains a tool to determine whether incineration of waste gasses can be avoided by the use of water borne inks.

In case less than 75 to 80% water borne inks are used, incineration can generally not be avoided. The incinerator may be smaller and may have lower operational cost, but the savings will be considerably less important.

2.5 Green field or existing plant?

It is obvious that the savings through water borne inks would be greatest where a completely new flexography plant could be taken into use. True ‘green field’ printing plant (with both new building and new machinery) are however extremely rare. Where new buildings are erected, existing machinery is moved into it. Where new machines are bought, they will be placed in existing buildings, next to older machines that are not yet to be replaced.

Where a green field plant is erected there will be important additional savings in case of water borne inks. Green field plants are however extremely rare in the flexible packaging industry. This study consequently focuses on existing plants. Cost savings that will occur in the case of a green field site will be indicated separately.

See also § 8.3 'Result green field plant'

2.6 Cost items

2.6.1 Money & Management time

A distinction is made between 'real money' cost and the use of management time. Both are affected by switching to water borne inks. The difference in real money cost can easily be expressed in €. For management time this is not so obvious. A method has been found however, but the subject is treated separate from conventional cost items.

2.6.2 Identified cost items

In the table below shows the cost items that can easily be expresses in terms of 'real money', that have been identified as being influenced by a switch over from solvent based to water borne inks. Each of the items is discussed in a separate paragraph.

Chapter	Cost item
Ink and associated cost	• Cost of ink and solvents
	• Energy consumption of dryers
	• Removal and treatment of waste
Environment and safety	• Waste gas incineration
	• Reduction and control of fugitive solvent emissions
	• Waste water treatment
	• Storage
	• Application of Best Available Techniques
	• Prevention of explosive atmospheres
Other cost	• Anilox rollers
	• Image carriers
	• Tests
	• Miscellaneous

2.6.3 Issues taking up management time

In the table below shows the relevant issues that will take up management time and which are influenced by a switch over from solvent based to water borne inks. These items are discussed in a separate paragraph.

Chapter	Management time issues
Management time	• Tests etc for the introduction of water borne inks
	• Quantification and reporting of fugitive emissions
	• Submission of a reduction plan:
	• Annual solvent balances:
	• Complex environmental permit (IPPC):
	• Explosion protection document:
	• Compliance with Occupational Exposure Limits:

2.6.4 Approach to cost calculations

This study was performed from a printer's perspective. Wherever savings or an increase in the printer's costs due to water borne inks were not certain, a conservative approach was taken; always conservative from the printer's point of view.

In the case of investments, depreciation is calculated on the basis of the estimated technical or economical life of the equipment in question. For environmental equipment this is generally some 15 years. For calculation of the financial burden of the investment an interest rate of 6% is assumed, applicable to the average value of the equipment over its technical or economical life span.

Other non-recurring cost that must be allocated to the switch from solvent based to water borne inks, are amortised over a five year period. For the financial burden the same method as for investments is used.

3. MODEL PLANT

3.1 Purpose

All flexography plant have different equipment, have different buildings and are to a different extent prepared for the legal demands placed upon them with regard to environment, health and safety. This means that the cost arising from both the use of solvent based and water based inks will differ from plant to plant.

In order to investigate and compare the differences in cost between the use of solvent based and water borne inks as transparently as possible, three theoretical model plant (‘large’, ‘medium’ and ‘small’) were designed. This approach also provides a structure for cost comparisons in real life situations.

The reason to have three model plant rather than just one is that most differences in cost are not linear with plant size: one large flexography plant is not the same as four small plants in one building.

Some examples of differences between small and large plant:

- Larger plant employ faster machines, work more shifts and consequently pay higher wages.
- Larger plant is more capital intensive and their productivity per employee is also higher.
- In larger plant the average run length is longer
- In larger plant raw material cost as percentage of turnover is higher and the added value is lower

3.2 Limitations to the model plant approach

For most of the cost items mentioned in earlier sections, the model plant approach works fine. Some can however not be addressed adequately with this approach. The real life cost of these items varies too widely from plant to plant for a model plant comparison to be useful.

For the purpose of this study these items are treated separately in a qualitative manner.

Chapter	Cost item
Environment and safety	• Storage
	• Application of Best Available Techniques (IPPC)
	• Prevention of explosive atmospheres
Other cost	• Miscellaneous

Treating these cost items in a qualitative manner is conservative. Each of the cost items in this category will, if affected by a switch to water borne inks, be affected downwards. There are no hidden effects that are unfavourable to water borne inks.

3.3 Description

Three model plants were constructed: a small plant employing 25, a medium sized plant employing 50 and a large plant employing 100. They have 2, 3 respectively 4 flexographic presses and produce heavy duty bags, bread bags or other similar products.

For the purpose of this study, the most important difference between these plants is not so much the number of personnel, the turnover or the number of presses, but rather the annual amount of ink used and the average number of shifts per day.

The following table describes the model plant:

Model plant	**Unit**	**Large**	**Medium**	**Small**
Economic figures				
Personnel	x	100	50	25
Sales per employee	k€	150.0	130.0	115.0
Personnel cost per employee	k€	47.5	44.0	42.5
Added value	% of turnover	58%	60%	62%
Turnover	million €	15.0	6.5	2.9
Added value	million €	8.6	3.9	1.8
added value per employee	k€	86.3	78.0	71.3
Raw materials	k€	6,380	2,600	1,090
Personnel	k€	4,750	2,200	1,060
Depreciation	k€	950	390	160
Other cost excl raw materials	k€	2,070	900	390
EBIT[1]	k€	860	410	170
Production time				
Number of presses	No	4	3	2
Shifts @ 8h per day[2]	avg. p.d.	2.0	1.5	1.25
Days per week	days per week	5	5	5
Weeks per year	week p.a.	48	48	48
Production time p.a.	hours p.a.	3,840	2,880	2,400
Solvent based inks				
Total ink bought, 36% solids[3]	t/a	250.0	97.2	41.7
Solids in ink bought (64%)	t/a	90.0	35.0	15.0
Solvent in ink bought	t/a	160.0	62.2	26.7
Total solvent/solid ratio[4]		4.5	4.75	5.0
Total solvent consumption p.a.	t/a	405.0	166.3	75.0
Solvent bought	t/a	245.0	104.0	48.3
Price ink/kg	€	5.00	5.00	5.00
Price solvent per kg	€	0.65	0.65	0.65
Ink cost	k€	1,250.0	486.1	208.3
Solvent cost	k€	159.3	67.6	31.4
Total cost solvent & ink	k€	**1,409.3**	**553.7**	**239.8**

(1) EBIT: Earnings before interest and tax

(2) Shifts @ 8h per day: Average number of 8h shifts per day. The smaller the company the larger the proportion of production personnel is working in day shift only.

(3) Total ink bought, 36% solids: The reference actually used for most cost comparisons is the amount of solids in the inks. For the sake of the calculations it is assumed that the ink as bought contains 36% solids and 64% solvent. A different ratio does not affect the calculations if the per kg price of the ink and the amount of solvent purchased is adapted accordingly.

(4) Total solvent/solid ratio: The overall ratio between all the solvents used in the plant and all the solids in solvent based inks, varnishes and adhesives. Many factors influence this ratio. Large plants tend to have a lower ratio than small ones. In large flexible packaging plants the ratio is generally between 1: 4 and 1: 4.5. Where however relatively few adhesives, varnishes and white inks are used, and where older machines are used, the ratio tends to be higher. Small plants therefor generally have a higher ratio than larger plant. The higher the ratio the higher many of the costs associated to the use of solvent based inks. The ratios for the model plant have been chosen conservatively.

4. INK AND ASSOCIATED COSTS

4.1 Ink and solvents

4.1.1 Composition of inks

As delivered by the ink maker, water borne inks will often per kg be more expensive than solvent based inks. The ink cost must however not be compared on the basis of the per kg price only. For a full comparison it needs to be taken into account that the composition of solvent based and water borne inks as delivered to the printing plant differ fundamentally.

The following typical composition of solvent based and water borne inks as delivered to the printing plant has been used throughout the calculations:

Inks		Solvent Based	Water Borne
Pigment	%	14%	17%
Other solids	%	22%	25%
Total solids	**%**	**36%**	**42%**
Solvent	%	64%	3%
Water	%	0%	55%
Total fluids	**%**	**64%**	**58%**

4.1.2 Other factors to be taken into account

Where two different inks need to obtain the same effect on the substrate, the amount of pigment per m² needs to be the same. The cost comparison should therefore be based upon the amount of pigment brought onto the substrate.

In addition, the following need to be taken into account:

- Solvent based inks require considerable amounts of solvent for viscosity adjustment and to compensate for solvent evaporation from the ink fountain during printing.
- Water borne inks are practically machine-ready when they arrive at the printing plant and need no additional solvent.
- In both cases cleaning agents are necessary. Where solvent based inks are used these are generally the same solvents as used in the ink. Often some 5% of the total solvent consumption is used for cleaning. For water borne ink, different solvents or solvent free cleaning agents can be used. The cost for these is assumed to be equal to the cost in the case of solvent based inks; equivalent to the cost of 5% of the solvent consumption.

4.1.3 Cost comparison

The per kg price of water borne inks will be somewhat higher than the per kg price of solvent based inks. An exact percentage can not be given, though it is very unlikely that the price difference will be more than 20%.

For the purpose of comparison, three different price levels for water borne inks are distinguished: 10%, 15% and 20% over the price for equivalent solvent borne inks.

For the medium sized model plant the complete calculation is presented below:

Direct ink costs		**Medium model plant**			
Inks		**SB**	**WB**	**WB**	**WB**
Pigment in ink bought [1]	%	14%	17%	17%	17%
Other solids in ink bought [2]	%	22%	25%	25%	25%
Total solids in ink bought	*%*	*36%*	*42%*	*42%*	*42%*
Solvent in ink bought	%	64%	3%	3%	3%
Water in ink bought	%	0%	55%	55%	55%
Pigment in ink bought[1]	t/a	13.6	13.6	13.6	13.6
Other solids in ink bought	t/a	21.4	20.0	20.0	20.0
Total Solids in ink bought	*t/a*	*35.0*	*33.6*	*33.6*	*33.6*
Solvent in ink bought	t/a	62.2	2.4	2.4	2.4
Water in ink bought	t/a	-	44.0	44.0	44.0
Total ink bought	**t/a**	**97.2**	**80.1**	**80.1**	**80.1**
Ink cost per kg relative to SB ink [3]	%	100%	110%	115%	120%
Ink cost per kg	**€/kg**	**5.00**	**5.50**	**5.75**	**6.00**
Total ink cost	**k€**	**486.1**	**440.4**	**460.4**	**480.4**
Solvents					
Overall solvent/solid ratio [4]	ratio	4.75			
Total solvent consumption	t/a	166.3			
Solvent bought (incl. cleaning)	t/a	104.0	8.3	8.3	8.3
Solvent cost	€/kg	0.65	0.65	0.65	0.65
Solvent cost	**k€**	**67.6**	**5.4**	**5.4**	**5.4**
Subtotal ink & solvent cost	**k€**	**553.7**	**445.8**	**485.8**	**485.8**
Savings water borne	**k€**		**108.0**	**88.0**	**67.9**
Savings water borne %	**%**		**19%**	**16%**	**12%**

(1) Pigment in ink bought: In the case of the water borne inks subject of this study, the pigments have a performance per kg very similar to those in the equivalent solvent based inks. The amount of pigment is the same in all cases.

(2) Other solids in ink bought: Binders and additives

(3) Ink cost per kg relative to SB ink: The three columns for water borne inks correspond top different price levels relative to the equivalent solvent based in: +10%. +15% and +20%

(4) Overall solvent/solid ratio: The overall ratio between all the solvents used in the plant and all the solids in solvent based inks, varnishes and adhesives. See explanation with table on model plant.

From the section above the following can be concluded:

> The cost of solvent based and waterborne inks should be compared on the basis of the pigment content and should take the cost of solvents into account. Where this is done, the cost of water borne inks proves to be substantially lower than the cost of solvent based inks, in spite of a higher per kg price.
>
> The saving obviously depends on the price of water borne inks. Where per kg water borne inks are assumed to be 10, 15 or 20% more expensive than solvent based inks, savings of 19, 16 or 12% respectively are possible for the medium sized model plant.

4.1.4 Effect on model plant

For the purpose of this study a conservative approach was taken. It was assumed that the per kg price of water borne inks is 20% higher than the price of solvent based inks. The percentage of savings varies slightly with the size of the model plant. This is caused by the relatively higher solvent consumption per kg of ink in smaller plant.

The results for all three model plant are calculated as follows:

Total ink cost		**Large**		**Medium**		**Small**	
Inks		**SB**	**WB**	**SB**	**WB**	**SB**	**WB**
Pigment in ink bought	%	14%	17%	14%	17%	14%	17%
Other solids in ink bought	%	22%	25%	22%	25%	22%	25%
Total solids in ink bought	*%*	*36%*	*42%*	*36%*	*42%*	*36%*	*42%*
Solvent in ink bought	%	64%	3%	64%	3%	64%	3%
Water in ink bought	%	0%	55%	0%	55%	0%	55%
Pigment in ink bought	t/a	35.0	35.0	13.6	13.6	5.8	5.8
Other solids in ink bought	t/a	55.0	51.5	21.4	20.0	9.2	8.6
Total Solids in ink bought	*t/a*	*90.0*	*86.5*	*35.0*	*33.6*	*15.0*	*14.4*
Solvent in ink bought	t/a	160.0	6.2	62.2	2.4	26.7	1.0
Water in ink bought	t/a	-	113.2	-	44.0	-	18.9
Total ink bought	**t/a**	**250.0**	**205.9**	**97.2**	**80.1**	**41.7**	**34.3**
Ink cost per kg relative to SB ink	%	100%	120%	100%	120%	100%	120%
Ink cost per kg	**€/kg**	**5.00**	**6.00**	**5.00**	**6.00**	**5.00**	**6.00**
Ink cost	**k€**	**1,250.0**	**1,235.3**	**486.1**	**480.4**	**208.3**	**205.9**
Solvents							
Overall solvent/solid ratio	ratio	4.50		4.75		5.00	
Total solvent consumption	t/a	405.0		166.3		75.0	
Solvent bought	t/a	245.0	20.3	104.0	8.3	48.3	3.8
Solvent cost	€/kg	0.65	0.65	0.65	0.65	0.65	0.65
Solvent cost	**k€**	**159.3**	**13.2**	**67.6**	**5.4**	**31.4**	**2.4**
Subtotal ink & solvent cost	**k€**	**1,409.3**	**1,248.5**	**553.7**	**485.8**	**239.8**	**208.3**
Savings water borne	**k€**		**160.8**		**67.9**		**31.4**
Savings %	**%**		**11%**		**12%**		**13%**

For the model plant it can be concluded that the ink and solvent cost in the case of water borne inks will decrease the annual cost for ink and solvent with at least 160, 68 and 31.000 € in the large, medium and small plant respectively. ‘At least’ because of the assumption that water borne inks will be 20% more expensive per kg than their solvent based equivalent.

In general it can be concluded that the total ink and solvent cost may at least be reduced by at least 10% of the equivalent cost of solvent based inks and solvents.

4.2 Energy

The evaporation of water requires more energy than the evaporation of the same amount of solvent. It is often argued that drying water borne inks must therefore be more expensive. In practice this is however hardly the case. Several factors favourably affect the energy requirements for drying water based inks:

- The amount of water in machine ready water based inks is only a third (!) of the amount solvent in machine ready solvent based inks (some 55% of the machine ready weight versus 80%)
- Drying water borne inks does not lead to a risk of explosions in the dryers and water borne inks do not know problems with residual solvent. This means that the air in the dryers may be re-circulated more often. Less fresh air needs to be heated.

Where water borne inks are already used today, the practical experience is that the drying temperature or airflow may need to be raised slightly to assure proper drying of water borne inks. The additional cost is however not noticeable and extremely small compared to other cost factors.

It can be concluded that the difference between solvent based and water borne inks for energy cost for dryers is negligible.

4.3 Waste

Where mixing and preparation of inks and collection of press returns is done with the same care, the percentage-wise losses for solvent based and water borne inks will be the same.

Still, the use of water borne inks may give rise to higher waste disposal cost. This is caused by the difference in in-house treatment of the waste ink. Waste solvent based ink will be distilled, The recovered solvent will be used for cleaning purposes and the sludge will be disposed of as hazardous waste. Waste water borne ink will be filtered. The clean water will be discharged and the sludge will be also disposed of as hazardous waste.

The amount of sludge is however different. Typical sludge from distillation will contain 75% solids. Typical sludge from filtration of water borne inks will contain 35% solids. The total quantity of sludge will therefore be doubled in the case of water borne inks.

Where very large amounts of sludge need to be disposed of, the difference in composition may also influence the per kg price of removal and treatment. Sludge from solvent based inks has a higher caloric value than sludge from water borne inks. This difference in price only comes into play in the large model plant. In both other model plant only the different quantity causes a difference in cost.

Assuming a 5% loss of ink as waste, the following comparison can be made.

<u>Waste disposal</u>		**Large**		**Medium**		**Small**	
		SB	**WB**	**SB**	**WB**	**SB**	**WB**
Solids in ink bought	t/a	90.0	86.5	35.0	33.6	15.0	14.4
Loss as waste 5%	t/a	4.5	4.3	1.8	1.7	0.8	0.7
Solids in sludge	%	75%	35%	75%	35%	75%	35%
Sludge	t/a	6.00	12.35	2.33	4.80	1.00	2.06
Removal cost [1]	€/kg	0.75	1.00	1.00	1.00	1.25	1.25
Removal cost	**k€**	**4.50**	**12.35**	**2.33**	**4.80**	**1.25**	**2.57**
Difference in cost	**k€**		**7.85**		**2.47**		**1.32**

(1) Prices based upon the situation in the Netherlands. Higher prices for smaller volumes and only where large volumes are involved will the caloric value of solvent based products lead to lower removal and treatment prices

From the example above, it can be seen that the cost for removal of waste from water borne inks will be higher than same cost for solvent based inks.

For the model plat it can be concluded that the waste disposal cost for water borne inks will <u>in</u>crease the annual cost with 7,900; 2,500 and 1,300 € in the large, medium and small plant respectively.

In general it can be concluded that the use of water borne inks will increase the total ink and solvent cost by some 0.5% due to higher waste disposal cost.

5. COST FOR ENVIRONMENT AND SAFETY

5.1 Waste gas incineration

5.1.1 Design airflow

Incinerators are expensive. They require a substantial investment; varying from some € 400,000 in small plant to well over € 1,000,000 in very large plant. The investment depends largely on the maximum airflow for which the incinerator needs to be designed.

The necessary investment is not at all proportional to the size of the flexography plant or even to the amount of solvents annually used. Small flexography plants need relatively much larger incinerators than large plant. A Flemish study into this subject even showed that the investment in incineration in small plant was on average not lower than in large plant.

This is caused by the following factors.

- The smaller the plant, the fewer the number of shifts and, relatively, the larger the number of presses and dryers and therefore the larger the maximum airflow relative to the production volume.
- The smaller the plant, the lower the average ink coverage and therefore the larger the airflow relative to the amount of solvents emitted.
- The smaller the plant, the shorter the job length and consequently the larger the proportion of the time necessary for make ready.
- The smaller the plant, the older the presses and the dryers. Older dryers tend to be less sophisticated and use more air for the same drying effect, they also tend to have less recirculation of drying air, and therefore a higher airflow for the same production volume.

Incineration cost have been calculated on the basis of a maximum airflow of 80.000, 45.000 and 30.000 m³/h for the large, medium and small model plant respectively. This is based upon the following calculation and assumptions:

Incinerator		**Large**	**Medium**	**Small**
Total solvent consumption p.a.	t/a	202.5	83.1	37.5
Capture efficiency	%	85%	80%	80%
Average concentration [1]	g/m³	2.25	2.00	1.75
Solvents to incinerator	t/a	344.3	133.0	60.0
Airflow in mio m³/a	mio m³/a	153.0	66.5	34.3
Average airflow in m³/h	m³/h	39,844	23,090	14,286
Design maximum airflow [2]	**m³/h**	**80,000**	**45,000**	**30,000**

(1) Average concentration: The figures used are conservative for flexographic printing. Where concentration are lower, the airflow is larger and a larger incinerator is necessary. Both capital cost and operational cost will be higher.

(2) Design maximum airflow: The design maximum airflow corresponds to some 15 to 20.000 m³/h per flexographic press, which is not unusual.

5.1.2 Capital cost

A small incinerator including the necessary ducting and preparatory work, capable of coping with 10,000 m³/h will cost some € 200.000. The necessary investment rises with some € 10 for each additional m³/h in capacity needed.

In order to calculate the annual capital cost an economic life of 15 years and a 6% interest rate are assumed,

Incinerator: capital cost		Large	Medium	Small
Design maximum airflow	**m³/h**	**80,000**	**45,000**	**30,000**
Investment incineration	k€	900.0	550.0	400.0
Depreciation 15 years	k€	60.0	36.7	26.7
Interest loss 6% on 50% of inv	k€	27.0	16.5	12.0
Total annual capital cost	**k€**	**87.0**	**53.2**	**38.7**

From the table above the following the following can be derived:

For the model plant it can be concluded that annual capital cost of incineration increase the annual environmental and safety cost in the case of continued use of solvent based inks. For the model plant this comes to 87,000; 53,000 and 39,000 € in the large, medium and small plant respectively.

In general it can be concluded that the annual capital cost of incineration corresponds with 6 to 16% of the annual ink and solvent cost depending on the size of the plant, where 6% corresponds to an annual ink consumption of 250 tons and 16% to an annual ink consumption of some 40 tons.

5.1.3 Operational cost

It is assumed that all three model plant would buy a regenerative incinerator, thus minimising their operational cost. The operational will consist of:

- Operation and maintenance
- Electricity for main fan and burner fan
- Fuel and electricity for cold starts
- Fuel for non-auto thermal operations

The following cost estimations are based on empirical data for real life incinerators.

Incinerator: operational cost		Large	Medium	Small
Maintenance & operations: 3% of investment [1]	k€	27.0	16.5	12.0
Electricity main & burner fan: € 0,1/1000 m³ [2]	k€	15.3	6.7	3.4
Number of cold starts [3]	x	250	250	250
Fuel & electricity for cold starts [4]	€/start	35.6	21.4	14.7
Fuel & electricity for cold starts	k€	8.9	5.4	3.7
Fuel for non-auto thermal operation [5]	k€	-	-	-
Total annual operational cost	**k€**	**51.2**	**28.5**	**19.1**

(1) Maintenance & operations: After some teething trouble most incinerators require little attention and maintenance. It is estimated that the total annual cost for operations and maintenance will amount to some 3% of the investment.

(2) Electricity main & burner fan: Assuming an electricity price of € 0.05 per kWh and taking into account the long periods where the main fan will only work at a proportion of it's capacity, the cost for moving each 1000 m³/h can be estimated at some € 0.10. The total m³ to be moved is equal to the average airflow multiplied with the operating hours of the plant.

(3) Number of cold starts: When the incinerator is not used, the ceramic heat exchangers cool down. They need to be reheated. None of the model plant has a night shift and there is consequently a cold start every working day.

(4) Fuel & electricity for cold starts: The cost for one cold start depends on the time that the installation has been idle (the longer, the colder) and it's size (the larger the more heat is necessary). Assuming a price for natural gas of € 0.25 per m³ and therefore € 0.028 per kWh the price per cold start has been estimated separately for each of the three model plant, taking into account both the larger number of shifts (and the resulting shorter cool down time) and the larger capacity for the larger model plant.

(5) Fuel for non-auto thermal operation: The average solvent concentration in each of the model plant is above the concentration at which the regenerative incinerator can work without additional fuel. In practice of course there will be periods of limited activity when fuel needs to be added, but this will not be often and the costs are considered negligible.

From the table above the following the following can be derived:

> For the model plant it can be concluded that annual operational cost of incineration will increase the annual environmental and safety cost in the case of continued use of solvent based inks. For the model plant this comes to at least 51,000; 29,000 and 19,000 € in the large, medium and small plant respectively. 'At least' because it is assumed that no fuel is ever needed to keep the incineration process going.
>
> In general it can be concluded that the annual operational cost of incineration corresponds with at least 3.5 to 8% of the annual ink and solvent cost depending on the size of the plant, where 3.5% corresponds to an annual ink consumption of 250 tons and 8% to an annual ink consumption of some 40 tons.

5.2 Reduction of fugitive emissions

The Solvent Emissions Directive applies to every flexography plant where more than 15 tons of solvent per year are used. The directive not only prescribes waste gas abatement, but also limits the fugitive emissions to 20 or 25% of the solvent input. In other words a minimum of 75% to 80% of the evaporated solvents must be captured and sent to the incinerator.

In order comply with the Fugitive Emission Limit Values of the Solvent Emission directive, the following is necessary:

Maximise capture efficiency

- Automatically send waste gasses from the dryers to the incinerator well before make ready press speed is reached.
- Connect the ventilation exhaust of the automatic washing machines to the incinerator.

- Avoid using solvent based products on machines that are not connected to the incinerator.
- Prevent defects to bypasses, dryers etc.

Reduce emissions that cannot be captured

- Minimise emissions due to evaporation from ink fountains during production.
- Minimise the use of volatile solvents for cleaning floors.

Maximising capture efficiency is part of an appropriate design of the incinerator and its ducting. No cost additional to that already mentioned under 'incineration' is involved. It must however be noted that obvious possible savings on the size of the incinerator, the automatic operation of the incinerator etc may lead to excessive fugitive emissions.

Reducing emissions that cannot be captured may involve additional cost. Especially the reduction of emissions from ink fountains may often require the application of chamber doctor blades.

Both the compliance with ATEX and the successful application of water borne inks would probably demand the application of chamber doctor blades. It is therefore assumed that the need to apply chamber doctor blades will occur anyhow and does not cause additional cost for either continued use of solvent based inks or the application of water borne inks.

From the above the following the following can be derived:

> Assuming that the incinerator, it's ducting and automatic operation are well designed, it can be concluded that the need to reduce fugitive emissions in case of continued use of solvent based inks does not increase the annual environmental and safety cost.

5.3 Waste water treatment

5.3.1 Techniques

No harmonised European legal requirements with regard to waste water treatment in flexography plant exist. In most European countries however in-house treatment is required of waste water polluted with remainders of water borne inks.

Different techniques for the treatment of this waste water are available. The most simple one being the collection of all polluted water and disposing of it as hazardous waste or leaving the polluted water to evaporate and disposing of the sludge. These techniques, if combined with methods to prevent as much as possible the occurrence of waste water, may indeed be sufficient for small plant.

For the purpose of the cost calculations however it is assumed that a ultra filtration system technique is used. Waste water is filtered, clean water is discharged into the sewage system, and the sludge is disposed of as hazardous waste.

5.3.2 Cost of waste water treatment

The cost of the waste water treatment system will of course vary from plant to plant, mainly depending on the cleaning techniques employed.

For the purpose of these cost calculations it is assumed that the ultra filtration system costs € 25,000 in investment for the small and medium sized plant and € 50,000 for the large plant.

The capital cost can be calculated as follows

Model plant		Large	Medium	Small
Waste water treatment				
Investment waste water treatment	k€	50.0	25.0	25.0
Depreciation 15 years	k€	3.3	1.7	1.7
Interest 6% x 50%	k€	1.5	0.8	0.8
Annual capital cost water treatment	**k€**	**4.8**	**2.4**	**2.4**

It is assumed that the operational cost for the waste water treatment is offset by the saving on operational cost for distillation. The cost of the disposal of the sludge is addressed in the chapter 'Ink and associated costs'. Only the annual capital cost needs to be taken into account:

From the above the following the following can be derived:

> For the model plant it can be concluded that the need for waste water treatment increases the annual environmental and safety cost in the case of water borne inks. Only the capital cost is taken into account as the operational cost is offset by the savings in the operational cost of distillation. The increase in cost is 4,800; 2,400 and 2,400 € for the large, medium and small model plant respectively.
>
> In general it can be concluded that that the need for waste water treatment increases the annual environmental and safety cost with some 0.1 to 0.3%, where the 0.1% corresponds to an annual ink consumption of 250 tons and 0.3% to an annual ink consumption of some 40 tons.

5.4 Application of BAT

5.4.1 IPPC permit

From 2007, every flexography plant with a capacity to consume more than 200 tons of solvent per year will need to have a comprehensive environmental permit in compliance with the 'Integrated Pollution Prevention and Control Directive' (IPPC).

Considering its solvent consumption of over 400 t/a, the large model plant would need such a permit. The medium sized model plant with a consumption of 166 t/a would be a borderline case, since the directive speaks of 'consumption capacity' and not of 'consumption'. A plant using 166 t/a may be argued to have the capacity to use a bit more.

The management time and consultancy cost related to the IPPC permit are dealt with in a later chapter.

Annex 2 of this report contains a tool that can be used to determine if an IPPC permit can be avoided by the application of water borne inks.

5.4.2 Best Available Techniques

The IPPC permit will need to prescribe the application of 'Best Available Techniques' (BAT).

In many European countries 'ordinary' environmental permits are already based on something equivalent to 'BAT'. In these countries the IPPC permit will not be very different from what otherwise would be required in a brand new permit. The important issue here is however the timing. Where perhaps the present permit may last many more years, the need for an IPPC permits brings forward in time the moment where all existing facilities are scrutinised by environmental authorities. New and additional environmental investments will as a result be brought forward in time.

'BAT' will apply to both the solvent emissions and all other environmental issues. This includes the prevention of the production of waste, the consumption of energy, storage of raw materials and waste, etc.

Two important possible requirements in a new IPPC permit will be:

- Reduction of solvent emissions beyond the requirements of the Solvent Emissions Directive. Especially the prevention of fugitive emissions may meet stricter requirements.
- Safe storage of solvent based products in general and of solvents in tanks will be expected to meet the most recent standards.

To what extent stricter requirements to the prevention of fugitive emissions lead to additional cost very much depends on the plant. In the worst case it may require an investment of several hundred thousand, but in many other cases these cost will not noticeably exceed the cost necessary for meeting the solvent emissions directive. No estimation can be made.

For the cost associated to safe storage of solvents and solvent based inks, see the next section.

> It can be concluded that in some European countries the IPPC permit and the application of BAT will lead to an increase in cost in the case of continued use of solvent based inks. In other countries the IPPC permit will bring forward the moment of new and additional environmental investments.
>
> Especially the safe storage of solvent and solvent based inks and further reduction of fugitive emissions may require early additional investment.

5.4.3 Avoiding an IPPC permit

Where flexography plants mainly use water borne inks, an IPPC permit can be avoided. The 'capacity of solvent consumption' of even the largest plant is easily reduced to below 200 tons per year. One of the most simple methods being a restriction of annual solvent consumption in the non-IPPC permit to a figure lower than 200 t/a.

5.5 Storage

The storage of highly volatile products such as solvents and solvent based inks is more expensive that the storage of non-flammable water borne inks. Where an existing storage room for solvent based products needs to be adapted to modern safety standards, an investment of € 100,000 is no exception. Where underground tanks for solvents need to be renewed, a similar investment can be expected.

The annual cost of safely storing solvents and solvent based inks is easily some € 10 to 25,000 higher than the storage of an equivalent amount of water borne inks.

The annual cost for storing solvent based inks may be higher, but that does not mean that savings can be obtained by switching to water borne inks. Where today the storage of flammable materials is well organised and up to standard, a switch to water borne inks will hardly reduce the cost for many years to come.

If however the moment for investments in storage coincides with the possibility to switch to water borne inks, these higher storage cost can to a very large extent be avoided.

In the very long term of course, in ten or fifteen years for example, the moment will arrive when even today's most modern storage facilities need to be adapted or renewed. This means that, given enough time, there will always be savings on storage costs when water borne inks are used.

The situation differs enormously from plant to plant. It is not possible to introduce the cost for storage in a sensible way into the model plant.

> It can be concluded that the storage of solvent and solvent based inks is considerably more expensive than storage of water borne inks. Saving can however only obtained when new investments in the safe storage of flammable products can be avoided.
>
> No savings on storage are taken into account in the model plant.

5.6 Explosive atmospheres: adequate measures and equipment

European directive on Protection of workers from Explosive Atmospheres (ATEX) is in force since 1999. It prescribes that, in June 2006 at the latest, every flexography plant will need to have an explosion protection document, assess and determine the explosion risks, classify the plant into explosion zones, take adequate measures to prevent explosive atmospheres and ignitions and work with adequately safe machinery and equipment.

These obligations only apply where materials are used that may give rise to explosive atmospheres. This is clearly the case with solvents and solvent based inks.

The first part of the obligation; to draw up an explosion protection document; assess and determine the explosion risks; classify the plant into explosion zones; involves consultancy costs and management time. This subject is addressed in a later chapter

The second part of the obligation; take adequate measures to prevent explosive atmospheres and ignitions and work with adequately safe machinery and equipment will in many cases necessitate investment and changes in working methods.

It is however impossible to estimate the cost of compliance with ATEX for the three model plant. Not only do flexography plants differ too much, but also no good standard list of measures to be taken in flexography plant exists. As a result, some plant will not need to change anything, and other plant may be faced with investments equal to that of half an incinerator.

Adaptations are almost unavoidable where open ink fountains are use, local extraction is missing, press room ventilation is less than formidable, viscosity control is not automatic, most cleaning is done by hand etc. The necessary changes are generally more expensive where presses, dryers, buildings and equipment are older.

The rules do not necessarily apply to the printing plant as a whole. Presses on which water borne inks are used are exempt. Also the rules vary with the frequency of use. Everyday use of solvents leads to stricter rules than occasional use. It is possible to reduce or avoid the cost of compliance with ATEX by the application of water borne inks.

> It can be concluded that the cost of compliance with ATEX will vary widely from plant to plant. In some cases investment of well over € 100.000 may be necessary, in other cases, expenses will be limited to the going through the formality of making an adequate explosion protection document.
>
> No savings on ATEX are taken into account in the model plant.

6. OTHER COSTS

6.1 Anilox rollers

The solid content of water borne machine ready ink is substantially higher than that of solvent based inks. The total volume of water borne ink to be brought on the substrate is therefor less than half the amount necessary in the case of solvent based inks. This means that a number of anilox rollers will need to be replaced by rollers with a much finer screen.

The cost of course depends on the number of anilox rollers. This is determined by the number of presses, the number of colours per press and the number of sets of anilox roller per colour. The average economic lifetime of an anilox roller, the age of the existing anilox rollers and the percentage of rollers that needs to be replaced also influence the cost.

The actual cost per plant will vary greatly. Making a number of assumptions, an impression of the cost is obtained. For the model plant the results are the following:

Anilox rollers	-	Large	Medium	Small
No presses [1]	No	4	3	2
No colours per press	No	8	8	8
Sets of anilox per press [2]	No	2	2	2
Total anilox rollers	No	64	48	32
% to be replaced [3]	%	50%	50%	50%
Cost per anilox	€	3,500	3,500	3,500
Total investment	k€	112	84	56
Savings coming years [4]	k€	56	42	28
Effective additional investment	k€	56	42	28
Depreciation	%	20%	20%	20%
Depreciation 5 years [5]	k€	11.2	8.4	5.6
Loss interest 6% x 50%	k€	1.7	1.3	0.8
Annual cost (for 5 years)	**k€**	**12.9**	**9.7**	**6.4**

(1) No presses: Number of presses. The presses are assumed to be of the same width.

(2) Sets of anilox per press: Average number of complete sets of anilox rollers per press. Assumed to be two in each case.

(3) % to be replaced: A flexography plant will have anilox rollers of different screens. Some of these will be usable for water borne inks and will not be replaced. Also the switch over to water borne inks takes time. During that time, damaged aniloxes that would have needed to be replaced anyway, will be replaced by aniloxes with a finer screen. Taking these factors into account, it is assumed that 50% of the aniloxes needs to be replaced before the end of their technical life.

(4) Savings coming years: Replacing aniloxes before the end of their technical life will give rise to saving in the years ahead as the annual number of replacement will be lower.

Assuming that on average the aniloxes that are thus replaced are halfway their technical life, a later saving of half the investment will occur.

(5) Depreciation 5 years: In order to calculate cost on an annual basis, all cost related to the introduction of water borne inks need to be amortised. In order to remain conservative this is done over a period of five years.

> For the model plant it can be concluded that the replacement of the anilox rollers in the case of a switch over to water borne inks will increase the annual cost for a number of years. This comes to 11,000; 8,300 and 5,500 € annually for a period of five years in the large, medium and small plant respectively.
>
> In general it can be concluded that the replacement of anilox rollers will increase the annual cost by some 1 to 6% of the annual ink and solvent cost, where the 1% corresponds to an annual ink consumption of 250 tons on four presses and 6% to an annual ink consumption of some 40 tons on two presses.

6.2 Image carriers

Dot enlargement for water borne inks differs from that of solvent based inks. Therefore, in most cases, the image carriers for solvent based and water borne inks need to be different.

The cost of making image carriers for solvent based or for water borne inks is the same. For new jobs there will be no additional cost. Where repeat jobs are switched from solvent based to water borne inks however, the image carriers will need to be replaced and additional cost may be incurred.

The additional cost can however to a large extent be prevented by switching jobs from solvent based to water borne inks only when new image carriers are needed anyway for other reasons.

> In practice it is generally possible to make the switchover without substantial additional cost to image carriers. It can be concluded that the additional cost for replacement of image carriers is negligible.

6.3 Tests

The switch over to water borne inks requires testing, some additional education of press operators and personnel charged with cleaning image carriers and anilox rollers.

Three types of cost can be distinguished:

- Management time
- Machine and operator time for the test runs and learning purposes
- Raw materials to be used for test runs of which the end product cannot be sold to a customer

Management time: Management time for the introduction of water borne ink is addressed in the chapter dedicated to management time in general

Machine and operator time: Whenever in printing plant test runs are needed that are not paid for by a customer, these runs take place in slack periods. Tests are never allowed to interfere with production and very rarely allowed to lead to overtime for the operators. It stands to reason that the same will be the case when a switch over to water borne inks is planned.

Where test runs do not replace any productive work, the hourly cost of machines and operators is negligible.

> For the purpose of this study it is assumed that test runs do not replace any productive work, and that the cost for machines and operators are negligible.

Raw materials: Very rarely will packaging materials that are produced during the early test runs be sold to customers. The use of raw materials for these runs therefore represents a cost.

Of course the actual cost very much depends on the number and length of the tests, the cost of the materials etc. In order to get an impression of the order of magnitude in the case of the three model plant, the following assumptions have been made:

- Tests take place on one press only
- A total of 200, 150 or 100 press hours are necessary for the testing in the large, medium and small plant respectively
- During testing much more time is spent on 'make ready' and the average press speed is much lower than in actual production, because only a short time at production speed is necessary to examine the results of the test.
- The cost of raw materials for the test is proportional to the total annual raw material cost of the plant.

On the basis of these assumptions the cost of the materials for the test runs can be estimated for the three model plant:

Material cost test runs		**Large**	**Medium**	**Small**
Total raw materials	k€	6,375	2,600	1,093
No of presses	x	4	3	2
Production hours [1]	h/a	3,840	2,880	2,400
Machine hours [2]	h/a	15,360	8,640	4,800
Raw material/machine hour [3]	€/h	415	301	228
Testing mach.hours total	h	200	150	100
Printing time test/production	%	50%	50%	50%
Printing speed test/production	%	25%	25%	25%
Raw materials per test hour [4]	€/h	52	38	28
Raw materials for tests	€	10,376	5,642	2,845
Amortise over 5 years [6]	€	2,075	1,128	569
Loss interest 6% x 50%	€	311	169	85
Annual cost (5 years)	€	2,386	1,298	654

(1) Production hours: Total production hours of the plant

(2) Machine hours: Production hours multiplied by the number of presses.

(3) Raw material/machine hour: Average raw material usage per available machine hour. Please note that all machine hours are counted including make ready, maintenance, etc.

(4) Raw materials per hour test run: Raw material per hour of test run based upon the raw material/machine hour, but reduced with the factors 50% and 25% for actual printing time and actual printing speed respectively.

(5) Amortise over 5 years: In order to compare these cost to other costs it is necessary to calculate an annual cost. For this purpose these costs are regarded as an investment and amortised in five years.

From the table above the following can be derived:

> For the model plant it can be concluded that the raw material cost for the test runs in the case of a switch over to water borne inks will increase the annual printing and associated cost. This comes to 2,400; 1,300 and 700 € in the large, medium and small plant respectively.
>
> In general it can be concluded that raw material cost for test runs will increase the annual cost by some 0.2 to 0.3% of the annual ink and solvent cost, where the 0.2% corresponds to an annual ink consumption of 250 tons and the 0.3% to an annual ink consumption of some 40 tons.

6.4 Miscellaneous

The most important cost items that will be influenced by a possible switch over to water borne inks have been addressed in the previous chapters. A number of less important items may additionally be influenced. Some of these additional items are:

- New presses and dryers will be somewhat cheaper since they need not be equipped for operation in a possible explosive atmosphere.
- Insurance and fire fighting equipment may be cheaper for the same reason.
- Periodic measurements of worker's exposure to solvent vapours will no longer be necessary. Periodic medical examinations of personnel may be simpler.
- Heating and electricity cost will be reduced because of lower ventilation requirements in the press room.
- Floors in press rooms no longer need to be resistant to solvents.
- In some countries the use or the emission of solvents is taxed. This tax is obviously saved where water borne inks are used

Non of these cost savings can well be quantified for the model plant. They will vary widely between printing plant, and except where tax is concerned, they will in most cases not be important relative to the cost items that were addressed earlier. No items were identified that might raise the cost in case of a switch to water borne inks. All will, if affected at all, lead to a lowering of cost.

> It can be concluded that in addition to the cost items addressed in earlier chapters, additional saving may occur when water borne inks are applied. These saving will vary widely between printing plants.
>
> Except where solvent tax is concerned, these miscellaneous saving will in most cases not be very important.

7. MANAGEMENT TIME

7.1 Identified issues

The successful introduction of water borne inks in a flexography plant is not necessarily a simple thing to achieve. The change over must be handled as an important project and will demand a considerable amount of time of middle and upper management.

On the other hand, the cumulation of new legislation that affects the continued use of solvent based inks also demands management time.

The following issues, related to the choice between solvent based and water borne ink have been identified that will, in the coming years, take up a considerable amount of management time:

Introduction of water borne inks: Before water borne inks can be introduced, experiments need to take place and customer approval may need to be sought.

Quantification and reduction of fugitive emissions: Where solvent based inks are used the fugitive emissions must be quantified in order to prove compliance with EU legislation. Where the bulk of the emissions are destroyed by an incinerator, the remaining 'fugitive emissions' are notoriously difficult to quantify. Calculation of the difference between the solvent consumption and the amount destroyed in the incinerator is not possible, since the amount destroyed cannot be established with nearly enough accuracy.

All sources of fugitive emission will need to identified and quantified separately. The most efficient approach will in many cases be to first reduce the emissions from each source to a minimum and thus also reduce the number of sources that are still large enough to warrant measurement.

Reduction plan: Where incineration is to be avoided by using water borne inks a 'reduction plan' needs to be submitted. This plan needs to prove that by using water borne inks the final solvent emissions will be smaller than those that would have arisen in the case of continued use of solvent based inks. A standardised calculation method is available.

Annual solvent balances: Both where solvent based and water born inks are used an annual solvent balance needs to be made. The complexity of these solvent balances however differs greatly.

The Solvent emission directive demands an annual solvent balance from flexible packaging plant proving that the emission limits are complied with. In the case of the application of incineration this annual solvent balance is complex. In the case of the application of water borne inks the annual solvent is very simple to make. In both cases the time required reduces over time.

Complex environmental permit: Larger plant using solvent based ink will need an environmental 'IPPC' permit. In most EU Member States the procedures and requests for such permits are considerably more complex than for 'normal' permits.

Explosion protection document: Where solvents are used the explosion risks need to be assessed and determined, the plant must be classified into explosion zones, adequate measures to prevent explosive atmospheres and ignitions need to be taken and adequately safe machinery and equipment needs to be provided. Even in cases where machinery, equipment and ventilation are up to standard, a considerable amount of time is necessary to document this.

Occupational Exposure Limits: Where solvents are used, workers need to be protected against exposure to solvent vapours and occupational exposure limits need to be complied with. In several EU Member States, periodic measurements are necessary.

7.2 Time spent in the model plant

7.2.1 Consultant, managers and fees

For the model plant the management time necessary for each of these items has been estimated and translated into costs.

With regard to cost, distinction is made between:

- Time for consultants
- Time for upper management (managing director or owner of the plant)
- Time for middle management (works managers, R&D managers, quality managers etc.)

It has been assumed that a consultant will be used only where their expertise cannot be missed or where they may save management a considerable amount of time.

Time is estimated in days. In order to translate time spent into cost, a daily 'fee' has been allocated to each of the three groups:

Group	Daily 'fee'
Consultants	€ 1,200
Upper management	€ 1,000
Middle management	€ 500

7.2.2 Estimation of time spent

An estimation was made of the time necessary. It is assumed that in the case of water borne inks some 20% of the production volume, concentrated on one press, will remain solvent based.

The table below gives the estimation for the medium sized model plant.

Estimation have been made for a period of five years.

Management time (5 yrs)	**Solvent based**			**Water borne**		
Group	**C[1]**	**UM[2]**	**MM[3]**	**C**	**UM**	**MM**
Introduction of water borne inks	-	-	-	-	5	20
Reduction plan	-	-	-	-	1	5
Solvent balance yr 1	-	-	3	-	-	1
Solvent balance yr 2-5	-	-	6	-	-	2
Reducing & measuring fugitive emissions	3	3	25	-	-	-
IPPC permit, request & implementation	4	4	15	-	-	-
ATEX requirements	4	4	15	1	1	4
H&S regulations	-	-	10	-	-	-
Total in days over 5 year period	11	11	74	1	7	32
Total in days over 5 year period		**96**			**40**	
Fee/cost in k€ per day	1.2	1.0	0.5	1.2	1.0	0.5
Total in k€ over 5 year period	**13**	**11**	**37**	**1**	**7**	**16**
Total in k€ over 5 year period		**61**			**24**	
Total in k€ per year		**12**			**5**	

(1) C: Consultant

(2) UM: Upper management

(3) MM: Middle management

The same estimations have been made for the other two model plant. For the large plant the estimation are somewhat higher, for the small plant somewhat lower. The results are shown below.

Model plant	**Large**		**Medium**		**Small**	
	SB	**WB**	**SB**	**WB**	**SB**	**WB**
Total days	127	62	96	40	70	34
Total in k€	81.5	35.2	61.2	24.2	44.6	21.2
Total in k€/yr	**16.3**	**7.0**	**12.2**	**4.8**	**8.9**	**4.2**
Difference	**57%**	**9.3**	**60%**	**7.4**	**52%**	**4.7**

Though it is hard to express management in monetary terms, it can for the model plants be concluded that a switch to water borne inks will reduce cost over a five year period by some € 9,300; 7,400 and 4,700 per year for the large, medium and small model plant respectively.

In general it can be concluded that the management and consultants time necessary for the introduction of water borne inks is less than half that of the necessary in management time for solvent related issues in the case of continued use of solvent based inks. If management time is allocated a daily fee, a switch to water borne inks would reduce cost by 0.7 to 2% of the annual ink and solvent cost, where the 0.7% corresponds to an annual ink consumption of 250 tons and the 2% to an annual ink consumption of some 40 tons.

8. RESULTS AND DISCUSSION

8.1 Existing plant

8.1.1 Result of the calculations

The table below shows the result of all the cost estimations for the three model plant. The situation described is one of existing presses in existing buildings, where enough water borne inks are applied to avoid incineration (at least 75 to 80%).

The cost mentioned are the cost increases or savings to be expected in either the case of continued use of solvent based inks or in the case of introduction of water borne inks.

Model plant :		**Large**		**Medium**		**Small**	
Solvent based/water borne	**Unit**	**SB**	**WB**	**SB**	**WB**	**SB**	**WB**
Inks and solvents	*k€/yr*	*1,409*	*1,249*	*554*	*486*	*240*	*208.3*
Ink & solvent (saving: -)	k€/yr		- 160.8		- 67.9		- 31.4
Energy	k€/yr	Difference negligible					
Waste disposal	k€/yr		7.9		2.5		1.3
Environmental Cost							
Incineration: capital cost	k€/yr	87.0	-	53.2	-	38.7	-
Incineration: operational cost	k€/yr	51.2	-	28.5	-	19.1	-
Reduction of fugitives	k€/yr	Included in well designed incineration & ATEX					
Waste water: capital cost	k€/yr		1.5		0.8		0.8
Waste water: operational cost	k€/yr	Offset by savings on distillation					
Other cost							
Anilox annual cost (5yrs)	k€/yr	-	12.9	-	9.7		6.4
Image carriers	k€/yr	Additional cost can be avoided					
Tests: machines and personnel	k€/yr	Additional cost can be avoided					
Tests: material (5yrs)	k€/yr	-	2.4	-	1.3	-	0.7
Management time							
Management time	k€/yr	16.3	7.0	12.2	4.8	8.9	4.2
Cost increase/decrease	**k€/yr**	155	- 129	93.9	- 49	67	- 18
Cost change, % of ink cost	**%**	11%	-10%	17%	-10%	28%	-9%
Total difference in cost	**k€/yr**		- 284		- 143		- 85
Difference as % of ink cost	**%**		- 21%		- 27%		- 36%

The table above only contains cost items that could adequately be estimated for the model plant.

Continued use of solvent based inks may however lead to additional cost increases on a number of other items, for which no reasonable estimation could be made:

Cost item	Effect of continued use of solvent based inks
Application of BAT	Important cost brought forward by IPPC
Storage	Additional cost will vary widely. May be very important
Explosive atmospheres	Additional cost will vary widely. May be very important
Miscellaneous	Additional cost will vary widely. Generally not important

8.1.2 Discussion

Continued use of solvent based inks:

In the case of continued use of solvent based inks, environmental legislation will give rise to substantial cost increases. For the model plant increases of at least 155; 94 and 67,000 € can be expected in the large, medium and small model plant respectively.

This means that in general, in the case of continued use of solvent based inks, cost increases of 11 to 28% of the annual ink and solvent cost must be expected, where the 11% applies in case of an annual ink consumption of 250 tons and the 28% to an annual ink consumption of some 40 tons.

In real life the cost increases for the use of solvent based inks may be substantially higher, since a number of items with the potential to further increase cost were not included in the model plant calculations.

Water borne inks:

Where water-borne inks are used, the cost increase associated with continued use of solvent based inks can be avoided.

In addition, the lower per m² price of water borne inks more than offsets the unavoidable cost necessary for successful introduction of these inks. By using water borne inks, savings of 10 or 9% of the annual ink cost can be attained.

Total difference

The total cost difference between continued use of solvent based ink and application of waterborne inks is between 21 to 36% of the annual ink and solvent cost, where 21% applies in case of an annual ink consumption of 250 tons and the 36% to an annual ink consumption of some 40 tons.

Considering the conservative approach taken, the actual savings obtainable with water borne inks, may very well exceed those presented here.

To reap this advantage it is enough to apply of 75 to 80% water borne inks and other solvent free products in most EU Member States.

8.2 Long term effect & green field plant

8.2.1 Long term effect

Throughout this report only cost increases and saving within a time horizon of a few years have been taken into consideration. Looking further ahead however, water borne inks unavoidably lead to additional and potentially large savings whenever important changes in the flexography plant occur. A new press need not have explosion free motors, new dryers need no safety features, new or renovated buildings don't need solvent resistant floors and explosion free light switches.

In order to get a feel for the order of magnitude of this long term saving, the difference between a green field plant and an existing plant was studied. The green field plant will immediately reap all the benefits, which will come to the existing plant in the long term.

8.2.2 Factors to take into account

In green field plant additional savings will be made. The most important items are:

Storage

- No special storage room for safe storage of solvent based inks
- No tanks, underground or otherwise, for the storage of solvents

Explosive atmospheres

- No explosion free equipment, lighting, switches etc in the press room
- No explosion free motors on presses
- No safety features on dryers
- No overlarge ventilation for press room, ink preparation room, cleaning room etc

Environment, Health & Safety

- No solvent resistant floor
- No local extraction
- Fewer partitions and fire doors in the building, resulting in a cheaper building and better logistics

8.2.3 Calculations

From the factors to be taken into account, it can be seen that the investment in a green field plant working with water borne inks will be substantially lower than in one working with solvent based inks. This will logically result in both a lower annual depreciation and lower operational cost.

For the lower operational cost, no credible estimation can be given, but the lower capital cost can be guesstimated.

For the purpose of a very rough and conservative estimation of the savings in capital cost, the following is assumed:

- Presses account for half the annual depreciation
- Buildings and equipment account for the other half.
- Presses for water borne inks could be 5% cheaper
- Building and equipment could be 15% cheaper.
- On average all investment could be 10% cheaper

- Therefore annual depreciation could be some 10% lower
- The average sum of fixed assets on the balance sheet is ten times the annual depreciation.
- Loss of interest on average 6% on balance sheet total for fixed assets.

The result of the calculation:

Model plant	**unit**	**Large**	**Medium**	**Small**
Fixed assets: 10 x annual depreciation	**million €**	**9.5**	**3.9**	**1.6**
Reduce fixed assets by 10%	k€	949	390	160
Saving depreciation on reduced assets 10% pa	k€	95	39	16
Reduced interest 6% on reduced assets	k€	57	23	10
Total reduced cost	**k€**	**152**	**62**	**26**
% of ink cost	**%**	**11%**	**11%**	**11%**

8.2.4 Discussion

Where annual depreciation figures for the model plant are 900, 400 and 160,000 €, the annual capital cost in a green field site would be lower by some of 150; 60 or 25,000 € for the large, medium and small model plant respectively.

This means in general that applying water borne inks in a green field plant leads to savings on capital cost, additional to those for existing plant, of some 10% of the ink and solvent cost. Consequently, existing plant will also reach this lower cost over time if they apply water borne inks since investment in new fixed assets or renovation of existing assets will be substantially cheaper.

8.3 Limited use of water borne inks

8.3.1 Result of calculations

A ‘limited use of water borne inks’ means that so much solvent based ink remains necessary, that incineration cannot be avoided. This obviously implies that the savings from a switch to water borne inks will be less significant.

The table below gives the expected effect of a 50% rather than full switch to water borne inks. The effects are described relative to the table in § 8.1.

Subject	**Expected effect**
Ink & solvent cost	
Inks and solvents	50% of the savings in case of water borne
Energy	Negligible
Waste disposal	50% of the increase due to water borne
Environmental cost	
Incineration: capital cost	75% of cost in case of solvent based
Incineration: operational cost	75% of cost in case of solvent based
Reduction of fugitives	Included in incineration etc
Waste water: capital cost	75% of cost in case of water borne
Waste water: operational cost	Offset by savings on distillation
Other cost	
Anilox annual cost (dep. 5 yr)	75% of cost in case of water based
Image carriers	Additional cost can still be avoided
Testing etc: machines etc	Additional cost can still be avoided
Testing etc: material (dep. 5 yr)	50% of cost in case of water borne
Management time	
Management time	Total of 75% of time in case of water borne and 75% of time in case solvent based.

Taking the above into account, the cost implications of a 50% switch over to water borne inks for the model plant are the following:

Model plant		**Large**		**Medium**		**Small**	
Solvent based	**Unit**	**100%**	**50%**	**100%**	**50%**	**100%**	**50%**
Inks and solvents	*k€/yr*	*1,409*	*1,329*	*554*	*520*	*240*	*224*
Inks and solvents cost difference	k€/yr	-	-80.4	-	-34.0	-	-15.7
Energy	k€/yr	Difference negligible					
Waste disposal	k€/yr	-	3.9	-	1.2	-	0.7
Environmental Cost		-	-	-	-	-	-
Incineration: capital cost	k€/yr	87.0	65.3	53.2	39.9	29.0	21.8
Incineration: operational cost	k€/yr	51.2	38.4	28.5	21.4	14.3	10.7
Reduction of fugitives	k€/yr	Included in well designed incineration & ATEX					
Waste water: capital cost	k€/yr	-	1.1	-	0.6	-	0.6
Waste water: operational cost	k€/yr	Offset by savings on distillation					
Other cost		-	-	-	-	-	-
Anilox annual cost (5yrs)	k€/yr	-	9.7	-	7.2	-	4.8
Image carriers	k€/yr	Additional cost can be avoided					
Tests: machines and personnel	k€/yr	Additional cost can be avoided					
Tests: material (5yrs)	k€/yr	-	1.2	-	0.6	-	0.3

Management time		-	-	-	-	-	-
Management time	k€/yr	16.3	17.5	12.2	12.8	8.9	9.9
Total cost increase	**k€/yr**	**155**	**57**	**94**	**50**	**52**	**33**
Cost change. % of ink cost	**%**	**11%**	**4%**	**17%**	**9%**	**22%**	**14%**
Potential savings		**7%**	**97.8**	**8%**	**44.1**	**8%**	**19.2**

The table above only contains cost items that could adequately be estimated for the model plant. Continued use of solvent based inks may however lead to additional cost increases on a number of other items. for which no reasonable estimation could be made:

Cost item	**Effect of continued use of solvent based inks**
Application of BAT	Important cost brought forward by IPPC
Storage	Additional cost will vary widely. May be very important
Explosive atmospheres	Additional cost will vary widely. May be very important
Miscellaneous	Additional cost will vary widely. Generally not important

8.3.2 Discussion

If in the model solvent based and water borne inks are used in approximately equal amounts savings will still occur. but they will be less important.

The cost increases due to continued use of solvent based inks cannot be completely prevented. but they can be reduced. For the model plant this reduction is estimated at some 98; 44 and 19,000 € per year for the large, medium and small model plant respectively.

This means that in general the a 50% switch to water borne inks will reduce cost increases associated with continued use of solvent based inks by some 7 or 8% of the annual ink cost.

In real life the savings may be much more important. By using water borne inks on presses or in parts of the building that are expensive to adapt to environmental requirements necessary in case of continued use of solvent based inks. cost may be reduced disproportionately.

A press may for instance have an extremely high dryer air volume. a very low solvent concentrations in exhaust air or may require very expensive ducting to the incinerator. It may also be extremely expensive to make a particular part of the building comply with ATEX.

In these cases it may be very much worthwhile to apply water borne inks. in order to avoid very high cost associated with continued use of solvent based inks on specific machines or in specific parts of the buildings.

For Johnson Polymer
23 February 2005
Sitmae Consultancy BV
Paul W.Verspoor MBA

ANNEX 1: IS IT POSSIBLE TO AVOID INCINERATION?

Question 1: Production processes flexography, packaging gravure, lamination, varnishing?	No	*Not covered by this document*
Yes		
Question 2: Solvent Consumption over 15 t/a?	No	No incineration necessary (not in scope) (1)
Yes		
Question 3: Any application of low solvent techniques considered technically possible? *(Examples: water based. UV curing, other low-solvent products, co-extrusion)*	No	Incineration unavoidable
Yes		
Action 1: Estimate the remaining solvent consumption in the case of application of all technically possible low solvent techniques. Question 4: Remaining solvent emissions over 15 t/a?	No	Avoiding incineration may be possible by getting out of scope (1)
Yes		
Action 2: Calculate reference emission and target emission (2) Question 5: Is the estimated remaining solvent consumption smaller than target emission?	No	Reduced size incinerator may be possible by applying reduction plan
Yes		
Avoiding incineration may be possible by applying reduction plan		

(1) Threshold of 15 t/a applicable in most EU countries. Check national legislation.

(2) Calculation of reference emission and target emission

Member State	**Category**	**Solids (t/a)**	**Reference emission**	**Target emission**	**Target emission**
NL	> 15 t/a	S	4 x S	20% x 4 x S	80% x S
D	?[3]	S	2.5 x S	25% x 2.5 x S	62.5% x S
Other EU[3]	15-25 t/a	S	4 x S	30% x 4 x S	120% x S
Other EU[3]	> 25 t/a	S	4 x S	25% x 4 x S	100% x S

(3) Always check national legislation

Annex 2: Is it possible to avoid an IPPC permit?

Question 1: Production processes flexography. packaging gravure, lamination or varnishing?	No	*Not covered by this document*
Yes		
Question 2: Actual solvent consumption close to or over 200 t/a? *(Remark: the official threshold is 'a consumption capacity of > 200 t/a'. Interpretation of this threshold varies between Member States. In flexography however capacity and actual consumption are generally close)*	No	Most probably no IPPC permit necessary
Yes		
Question 3: Any application of low solvent techniques considered technically possible? *(Examples: water based. UV curing, other low-solvent products, co-extrusion)*	No	IPPC permit unavoidable
Yes		
Action 1: Estimate the remaining solvent consumption in the case of application of all technically possible low solvent techniques. Question 4: Remaining solvent consumption well below 200 t/a?	No	IPPC permit probably unavoidable
Yes		
IPPC permit not necessary		

Annex 3: Literature

- Below a list of some of the literature that has been used for this study.
- See list with abbreviations below the literature list
- A number of these documents may be downloaded for www.Sitmae.nl

Author	**Year**	**Commissioned by**	**Translated title**	**Original title**
Sitmae Consultancy: P.W.Verspoor	October 2004	VROM (The Netherlands)	Fugitive solvent emissions in packaging gravure and flexography Part 1: Sources. amounts and possible reduction measures	Diffuse oplosmiddelemissies in verpakkingsdiepdruk en flexo: Deel 1: Bronnen. hoeveelheden en mogelijke reductiemaatregelen
Sitmae Consultancy: P.W.Verspoor	October 2004	VROM (The Netherlands)	Draft: Fugitive solvent emissions in packaging gravure and flexography Part 1: measuring and reducing	Concept: Diffuse oplosmiddel-emissies in verpakkingsdiepdruk en flexo: Deel 2: Meten en verminderen
Ministerie VROM en SZW	October 2004		Draft: Guidance note storage of hazardous materials in packaging	PGS 15: Concept Richtlijn opslag van verpakte gevaarlijke materialen
Flexible Packaging Europe	June 2004		Congress for the flexible Packaging Industry; Proceedings	
Joint Research Centre	May 2004	European Commission	IPPC: Draft Reference document on BAT on surface treatment using organic solvents	

Author	Year	Commissioned by	Translated title	Original title
European Commission	August 2003		Communication concerning the non-binding guide of good practice for implementing European Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres	
Citepa. Mr.J.Vincent	March 2003	UN-ECE	Flexography and gravure in the packaging. Final background document. EGTEI	
Environment Agency (UK)	February 2003		Sector Guidance Note SG6(03): Coating and surface treating using organic Compounds	
Ökopol. D.Jepsen, C.Tebert	February 2003	Umweltbundesamt (Germany)	Best Available Techniques in the Printing Industry	Integrierte Umwelschutz bei bestimmten industriellen Tätigkeiten. Teilband II; Bedrucken
Joint Research Centre	November 2002	European Commission	IPPC: Draft reference document on economic and cross media-effects	
Joint Research Centre	February 2003	European Commission	IPPC: Reference document on BAT in common waste water and waste gas treatment/management systems in the chemical sector	

Author	Year	Commissioned by	Translated title	Original title
Sitmae Consultancy: P.W.Verspoor	October 2002	Aminal (Belgium, Flanders)	Evaluation of the potential for the reduction of VOC emissions from the printing sector. Part 3: Measures to reduce emissions	Evaluatie emissiereductiepotentieel voor VOS emissies van de Grafische sector Deel 3: Emissiebeperkende Maatregelen
Joint Research Centre	November 2002	European Commission	IPPC: Reference document on the general principles of monitoring	
Sitmae Consultancy: P.W.Verspoor (complete report) VITO: F.Sleeuwaert (Chapter 9)	October 2002	Aminal (Belgium, Flanders)	Evaluation of the potential for the reduction of VOC emissions from the printing sector. Part 2: Solvent emissions directive and the printing industry	Evaluatie emissiereductiepotentieel voor VOS emissies van de Grafische sector Deel 2: Solventrichtlijn en de Grafische Sector
VITO: Ms.K.Briffaerts, H.van Rompaay, J.Duerinck	October 2002	Aminal (Belgium, Flanders)	Evaluation of the potential for the reduction of VOC emissions from the printing sector. Part 1: emission inventory. Prognoses, cost curves	Evaluatie emissiereductiepotentieel voor VOS emissies van de Grafische sector Deel 1: Emissie inventarisatie. prognose. kost curven
Sitmae Consultancy: P.W.Verspoor	January 2002	KVGO, SZW (Netherlands)	Cleaning in flexo and packaging gravure	Schoonmaak in flexo en verpakkingsdiepdruk
NNI	July 2001		Guidance note on zoning explosion hazards (gasses)	NPR 7910-1: Gevarenzone-indeling m.b.t. ontploffingsgevaar (gas)

Author	Year	Commissioned by	Translated title	Original title
TME (Instituut voor Toegepaste Milieu-Economie): H.van der Woerd. Sitmae Consultancy: P.W.Verspoor	February 2000	VROM (The Netherlands)	Study into VOC emission reduction potential for printing. flexible packaging (including printing on soft PVC)	VOS reductiepotentieel Grafische Industrie en verpakkingsdrukkerijen en bedrukken zacht PVC
Sitmae Consultancy: P.W.Verspoor VITO: Ms.A.Derden, Ms.A.Vaesen, R.Dijkmans Febelgra: J.Buysse Fetra: Ms.I.Vervloet	1998	Aminal (Belgium, Flanders)	Best Available Techniques for the Printing sector	Best beschikbare technieken voor de Grafische sector
Sitmae Consultancy: Ms.M.R.Wasenaar, P.W.Verspoor Tebodin: H.B.Gels	May 1995	VROM, KVGO, Kartoflex (The Netherlands)	Study into solvent recovery in flexible packaging	Onderzoek naar terugwinning van oplosmiddelen in verpakkingsdrukkerijen
Sitmae Consultancy BV: Ms.M.R.Wassenaar, P.W.Verspoor	February 1992	VROM (KWS-2000), KVGO, Kartoflex (The Netherlands)	Inventory of low solvent inks, varnishes and adhesives, part 1 (plus database)	Inventarisatie van oplosmiddelarme inkten. lakken en lijmen. deel 1 (met database)
Sitmae Consultancy: P.W.Verspoor Tebodin: P.W.Ywema	January 1992	Province of Utrecht, KVGO, Kartoflex (The Netherlands)	Disadvantages for the environment of water based inks, varnishes and adhesives	Milieubezwaarlijkheid voor water van waterafdunbare inkten, lakken en lijmen
Sitmae Consultancy BV: Ms.M.R.Wassenaar, P.W.Verspoor	August 1991	VROM/KWS-2000 (The Netherlands)	Problems in the use of water based inks. varnishes and adhesives for the production of flexible packaging materials	Toepassingsproblemen bij het gebruik van oplosmiddelarme inkten lakken en lijmen in verpakkingsdrukkerijen

Author	Year	Commissioned by	Translated title	Original title
Tebodin. P.Frijns	July 1991	VROM (Ministry of Environment), KVGO, Kartoflex (The Netherlands)	Study into the possibility to raise the permitted solvent concentrations in the drying air of flexible packaging manufacturers	Studie naar de mogelijkheid de toegestane oplosmiddelconcentratie in de drooglucht bij verpakkingsdrukkerijen te verhogen
Sitmae Consultancy: P.W.Verspoor Tebodin: H.B.Gels	June 1991	VROM, KVGO, Kartoflex (The Netherlands)	Further research into end-of-pipe abatement for flexible packaging (part 1 and part 2)	Nadere oriëntatie naar nageschakelde technieken voor verpakkingsdrukkerijen (deel 1 en deel 2)

NAMES AND ABBREVIATIONS USED IN THE LITERATURE LIST	
Aminal	*Flanders Ministry of Environment*
Citepa	*French Research institute*
ERA	*European Rotogravure Association*
Febelgra	*Belgian general printers association*
Fetra	*Belgian paper and board converters association*
FPE	*Flexible Packaging Europe*
Intergraf	*European general printers association*
Kartoflex	*Netherlands flexible packaging association*
KVGO	*Netherlands general printers association*
KWS 2000	*Netherlands Government/Industry cooperation project to reduce VOC emissions with 50% by 2000*
Maetis Consultancy bv	*Former name of Sitmae Consultancy BV. NL regulatory affairs consultant*
Tebodin	*Netherlands Research institute*
TME	*Netherlands Research institute*

NAMES AND ABBREVIATIONS USED IN THE LITERATURE LIST	
VITO	*Flemish Institute for Technological development*
VROM	*Netherlands Ministry of Environment*
SZW	*Netherlands Ministry of Social Affairs*
NNI	*Netherlands standardisation institute*