TOWARDS A SUSTAINABLE

Paper Cycle

Sub-Study Series

10 Converting and the Paper Cycle

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CONVERTING AND THE PAPER CYCLE

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1. INTRODUCTION

The term "converting" is formally defined as "the process of transforming one or more preformed raw materials to a state suitable for end use or further processing" (Chamberlain & Bowler 1992). For our purposes the term can be defined less abstractly as referring to those processes used to convert paper into paper products, for example the using of ink on paper, the lamination of paper to form cartons or the adding of glue to paper to make packaging. These processes are very often toxic in nature and can have significant implications for the environment.

In this study two conversion processes are focused on, that of putting ink on paper and that of adding adhesives to paper. The study will examine the environmental impacts of these two processes *from the point when the inks and adhesives actually come into contact with paper.* Particular emphasis is given how they affect the recyclability of paper and the waste disposal options available to it.

2. INKS

2.1. Environmental Impacts of Ink Application to Paper

Conventional Mineral Oil Based Inks

Conventional printing inks are mineral oil based inks. They are made up of the following components: two/three colouring agents, a number of solvents, binding agents and additives (Greenpeace, 1993). The relative proportion of each of these components varies according to the what the printing inks is to be used for.

In environmental terms the most significant immediate difficulty with the use of mineral oil based inks is their emission of volcanic organic compounds (VOC's) during the drying process which occurs after the inks have been applied to paper. VOC's are solvents and dilutents which are particularly a problem in terms of heatset, flexo, gravure and screen printing inks, where the drying relies on evaporation. There are a number of problems associated with VOC's, and solvents in particular, including their disposal after drying, their flammable nature, and the toxic and narcotic effects that result from them when vapour is inhaled. Many of the solvents that have been a particular cause for concern, such as methanol, benzene, methyl and ethyl cellosolve and chlorinated hydrocarbons, have been removed from most inks, however the lesser effects of the others are still of concern. For example trichloroethane, which in environmental terms contributes to the formation of trospospheric ozone and smog .

Three main techniques have been identified to stop the venting of solvents in to the atmosphere:

- Solvent Recovery
- Solvent Incineration
- Use of Alternative Inks (eg water based inks, vegetable oil inks, UV-cured inks)

Solvent recovery is when solvent vapour is absorbed onto an activated charcoal bed and later recovered by "sparging" with steam or heated inert gas. The problem with this option is that steam sparging is only effective with water immiscible solvents and the bulk of ink solvents have some water miscibility. Also the recovered solvent is a mixture of solvents of variable composition that is difficult to reuse.

Solvent incineration involves substantial capital costs. Heat recovery is needed to make the system economically viable. However the exhaust gas will be carbon dioxide. Further it is argued that oil derived organic solvents are a non renewable resource that should not be destroyed unnecessarily.

The difficulties of the first two options has led to an emphasis on the use of alternative "non VOC emitting" inks. The most commonly suggested alternatives to mineral oil based inks are Vegetable Oil Based Inks, Water Based Inks and UV-Cured Inks. Both vegetable oil based inks and water based inks by their very nature contain lower levels of solvents than mineral oil based inks, hence they result in lower levels of VOC emissions in the atmosphere. According to an estimate by Bill Zak (Adams-North 1992)the amount of VOC's emitted by water based inks will soon shrink to an estimated one percent however, it will be some years yet before emissions are down to zero. UV cured inks meanwhile result in absolutely zero emissions of VOC's already (Adams-North 1992).

Vegetable Oil Based Inks

Vegetable oil based inks are different from conventional mineral oil based inks in the sense that they contain "semi-drying" oils such as soy oil in their formulation. These semi-drying oils replace the mineral oils that are used in traditional inks.

The greatest use in terms of vegetable oil based inks has been with newspaper For example about 75% of the Belgian press runs vegetable black and coloured ink. In the United States meanwhile vegetable oil based inks are being used by half of the country's 9,100 newspapers, including 1,700 daily newspapers. The most noteworthy users are the Washington Times, Denver Post, Detroit Free Press and the Boston Globe. In the United Kingdom meanwhile more than 50 % of coloured newspaper ink is vegetable based (De Keyser, European Ink Maker 1994).

Users of vegetable based inks believe that the inks offer a number of advantages over mineral based inks, apart from low VOC emissions. In an article in European Ink Maker (August 1994) J R De Keyser of Trenal SA states that "Besides eliminating the possible risks for cancer (due to the presence of high PCA content in some mineral oils used in printing inks) and giving no VOC emissions, vegetable oil-based inks present many advantages as compared to mineral oil based when combined with adapted varnishes, including:

- Exceptional rub resistance
- Outstanding stability on the press
- Deeper black and increased colour intensity
- Quick adjustment of the ink/water balance in offset and therefore less paper waste
- Easy tuning during the printing
- More mileage

- Nearly no "dry back"
- No hazard labelling required"

Similar advantages were pointed out in a recent article written by Chris Williams in the World Graphics Art Technology Journal where he stated that "Apart from potential environmental benefits, there are technical advantages of better litho properties, cleaner printing, brighter colours, sharper printing, better transfers and better mileage" Williams also states that though vegetable oil is more expensive than mineral oil, the proportion of the total cost that it represents (by comparison with the pigment cost) is so small that there need be no increase in price for coloured inks (William, 1992).

Williams believes however that the mentioned advantages do not apply to black newspaper ink. He states that as far as black newspaper ink is concerned "The technical benefit are very much less apparent and the cost penalty is so much greater as to be prohibitive on most occasions. As a result, there is very little use of vegetable oil blacks, even in the United States" (Williams 1995)

Box 1: Soy Oil - The Most Popular Semi-Drying Vegetable Oil In the United States

In the United States virtually all of the semi-drying oil used in vegetable ink oils is soy oil (NAPIM, American Ink Maker 1993). Soy oil is widely used in coloured newsinks and in a wide variety of sheet offset (lithographic ink) products. It is used less often in black newsinks. This is partly due to the problems of dispersion and partly because of the cost. Soy oil is even less widely used in heatset offset inks systems, although heatset inks with low levels of soy oil are now becoming available (NAPIM, American Ink Maker 1993).

Jack Power a major advocate of soy oil states that "soy oil has several good qualities. It is a renewable resource that lessens dependence on foreign oil and therefore, helps the economy..soy oil has a very low VOC content compared to traditional hydro-carbon ink-oils."(Power, N Z Printer 1992)

He goes on to say that soy oil based inks are better for recycling as well, "because their low tack is much kinder and gentler on the weakened fibres of recycled paper" (Power, N Z Printer 1992)

Power does note however that soy oil does not make ink biodegradable, nor does it enable casual disposal of press returns. "The inks still contains pigment colouring and press returns are contaminated with wash up solvents and fountain chemistry and therefore are considered hazardous waste". (Power, N Z Printer 1992)

Water Based Inks

Water based inks have been used widely for flexo printing on multi wall Kraft sacks, corrugated cases, disposable tissues, labels and other paper products for years. Sales of water

based inks represent 20-25 per cent of flexo inks sales in the United Kingdom. This proportion is much higher in the United States (Williams, World Graphic Arts Technology 1992).

The attraction of water based inks is that they are totally non-flammable and do not give off objectionable vapours. When the ink has been dried the water vapour can safely be vented to the atmosphere and they have a lower potential for contaminating packaged products.

UV-cured Inks

UV-cured inks are another alternative to mineral oil based inks. UV cured inks are inks that have been subjected to ultra violet light which has caused a chemical reaction within the liquid ink, in order to harden it without releasing any emissions. Initially there was much concern about the safety of UV curing, however the process has been developed over the years so that it is now a safe technique.

UV-cured inks can be used in most of the applications for which conventional mineral oil based inks are usually used, and in some ways they have resistance properties that are better than alternative inks such as water based inks. However UV-cured inks have the disadvantage of requiring greater energy input during the drying process (Williams 1992).

In the United States the use of UV-cured inks has grown recently, particularly in rotary letterpresses. In the future according to Andy Dakos the growth of UV inks is expected to be in flexo printing (Adams-North, Package Printing & Converting 1992). Growth in the use of UV-cured inks is also expected in Europe where as a result of environmental regulations UV technology is being continually improved and developed (Adams-North, Package Printing & Converting 1992).

2.2 The Implications of Ink Application for Paper Recyclability

Ink on printed matter is a contaminant which has to be removed before recycling can take place. It is thought by the British Printing Industry Federation that the amount of dried ink on paper is so small that it constitutes only a minor contaminant (Printer and the Environment 1993). However the existence of even this small amount can render a batch of waste paper ineffective for recycling purposes unless the ink on the paper can be removed.

The removal of ink from paper or "deinking" is not a new practice. It was developed by Professor Claproth in 1774. Deinking as it is practised today involves the use of a slightly alkaline aqueous solution which separates the ink from the printed matter on which it has been used. A flotation process is then used to skim away the ink from the paper. Previously the ink was skimmed away via a washing process.

Research has shown that "conventional inks", being mineral oil based inks can be easily removed the paper on which they are printed. Hence they do not affect the recyclability of paper. Mineral oils are chemically inert bonding mixtures which do not change chemically under conditions of deinking, and they do not dissolve in water either. As such they can be easily removed from the paper.

Having said this there are certain exceptions where the deinking of conventional inks may be difficult. For example if the ink has been applied directly to paper fibres as opposed to the coating, then only recently produced paper can be deinked using the traditional methods of deinking with the known chemicals. This has been found by Scettler who conducted an experiment based on newspaper type paper which was printed with four listed printing inks on a printing press. A portion of the printed paper after being stored for a week at room temperature was subjected to a deinking process. The other portion of the paper was deinked after nine weeks. Scettler found that as the paper ages a different type of solution has to be used to deink successfully. (Scettler)

Unlike conventional inks research has shown that "vegetable oil based inks" do affect the recyclability of paper. According to Kubler, because vegetable oils, such as linseed oil, soya oil and wood oil, dry through oxidation, they obtain high mechanical toughness and strength. This makes it extremely difficult to deink the paper on which they are printed. Even just a few percent of vegetable oils can disturb deinking considerably.

However deinking of vegetable oil based inks is not completely impossible. Through the application of peroxide during deinking, vegetable inks can be separated from paper. (Scettler).

Water-based inks also create difficulties in terms of recyclability. According to Dr Robert Howard of Paprican this is because during deinking water based inks disperse into small particles which are difficult to float out. This means that a wash process has to be used. The wash process is typically a second choice for deinkers principally because it is not as effective as the float process and because it costs more in terms of capital and energy than float deinking.

2.3 The Implications of Ink Application on Waste Paper Disposal Options

There is dispute about whether the use of ink on paper has implications for the waste disposal options available for paper. The BPIF believe that printing ink films do not contain any materials that would inhibit the suitability of printed matter for incineration. At the very high temperatures involved, inks with their very low levels of chlorine and sulphur will not contribute to the production of toxic emissions (Printer and the Environment 1993).

In terms of landfill meanwhile the BPIF say that ink film is unlikely to have any effect on the anaerobic degradability of printed matter in a landfill (Printer and the Environment 1993).

3. ADHESIVES

3.1. Environmental Impact Of Adhesive Use On Paper

The conventional adhesives used for packaging are solvent based or contain isocyanate. In environmental terms both are hazardous (Packaging News August 1994). In the same way as the solvent in inks, adhesive solvent can be the cause of VOC emissions into the atmosphere.

Alternative adhesives that do not release any VOC emissions are available. These are usually

water based adhesives which are free of both isocyanates and solvents. Currently a number of water based systems are being used by UK converters in the manufacture of flexible packaging laminates. The use of water based adhesives requires no expensive machinery modifications and as they have a long pot life, result in less waste. Further they are thought to be of high strength and are suitable for a wide range of applications (Packaging News, August 1994)

3.2. The Implications of Adhesive Use On Paper Recyclability

Conventional adhesives can cause problems for paper in terms of recyclability. According to the British Printing Industry Federation (BPIF) just 1kg of adhesive can ruin over 100 tonnes of stock in terms of recyclability. The BPIF say that for an adhesive to be truly recyclable it must either be reused completely, in which case the adhesive has to be totally separated from fibres, reformed and used again in a secondary application or else it must be fully incorporated into the finished product which implies that the adhesive must travel through the mill system to give 100% retention on the fibres in the finished paper. The BPIF looked into the recyclability issue with regards to adhesives; their findings were published in a book entitled Printer and the Environment (1993). They looked at specifically at Book binding Adhesives.

In terms of book binding adhesives the BPIF noted that in the past soft tacky adhesives were used in mill systems which would not have fitted the above definition of recyclability at all. Today's conventional adhesives are composed of ethylene vinyl acetate (EVA), polyvinyl acetate (PVA), acrylic and styrene containing polymers. These adhesives do not completely fit the above stated definition however they are recyclable in the sense that they are dispersed or soluble in alkali or water or they are filterable in the pulping process. In both cases adhesives must be removed from the system and disposed of to make the paper on which it is used recyclable. The former (ie dispersed or soluble adhesives) are more difficult to deal with then the latter. It is extremely difficult to remove a buildup of such adhesives from the backwater system. Costly water treatment programmes are required to do this.

In the case of adhesives which are screened out during the pulping process, screen rejects, usually attached to fibre, must be disposed of ether in landfill sites or by incineration.

Whilst these approaches do not produce a totally recyclable adhesive they are certainly a step forward from the traditional adhesives that were used; they do allow the finished product to be recycled more effectively.

The real issue is how much of a step forward are they. In this sense we need to look at mill systems and ways of testing recyclability. Different mills employ different systems which can affect the ability to recycle certain materials in terms of handling contraries. Process variables such as pulping shear forces/speeds, temperature, consistencies, pH, dispersion/screening capabilities, de-inking processes and cleaner efficiency can have a major impact on the quality of the finished product and recycling efficiency in the mills. Adhesives acceptable to one mill may cause problems at other mills.

Due to the complexity and variability of different mill systems it is difficult to develop a standard test for adhesive recyclability in a laboratory which is valid. Many tests exist but

none really reflect the true ability of an adhesive to be recycled because they cannot accurately simulate the whole mill treatment system. Tappi UM 666 is most widely quoted as an adhesive recycling test. The test can however only be used as an initial guide or screening process as it a simple laboratory scale test. Currently the only true test of an recyclability is to run a full scale mill trial.

Adhesive removal is typically based on mechanical methods which exploit physical differences between adhesives and fibres. If mechanical methods are not practical or economical, then chemical techniques may be utilised. Such techniques exploit the chemical or surface chemical differences between adhesives and fibre. While all these techniques are essential to control recycling efficiency and product quality, in economic terms they can be very expensive. It is difficult to quantify the cost of dealing with adhesives accurately, however it is likely to be enough to hinder the encouragement of greater waste paper use. Most recycling mills now build the cost of removing adhesives, into their financial calculations as the "Cost of Quality". The question which recycling mills are interested in is how the "cost of quality" can be minimised or removed by technological developments in the adhesives field.

In terms of the future according to the BPIF the aim should be to incorporate adhesives into the paper. Adhesives may then be considered *totally* recyclable. If this is not possible the aim should be to completely reuse adhesives, after they have been separated from the fibre, rather than sending them to landfills or incinerators.

4. LEGISLATION ON INKS AND ADHESIVES

Recently a number of EC directives relating to printing inks have been issued. These were laid out in an article published in the Polymers Paint Colour Journal, entitled "European Legislation on Printing Inks" which was written by J.P Langhammer To begin with there is the IPC directive. The directive takes an integrated approach on pollution of water, air, production of waste and energy consumption and emission. Printing and printing ink manufacturers are not directly addressed by this directive, but are under its scope. The directive requires manufacturers to acquire a permit for solvent emission above certain levels.

The directive was planned to be effective for new installations as from 30th June 1995 and for existing installations from 30th June 2005.

Another directive that has been issued in Europe is the VOC Directive. In 1979 the United Nations Economic Commission for Europe (UNECE) issued a "Convention on Long Range Transboundary Air Pollution concerning the Control of Emissions of VOC's of their Transboundary Fluxes". The convention was signed by the European Community and separately by all the member states in November 1991. It obliged them to reduce their VOC emissions by 30% by the year 1999 (based on the 1988 emissions).

In reaction to the UNECE protocol and in view of the general environmental and public health aspects, in August 1991 the EC commission introduced a draft directive on the "Limitation of Emissions of Organic Solvents from Certain Industrial Installations and Processes". The driving force behind the directive was the fact that many EC member states

have already developed their own legislation, and amongst them there were such extreme positions as Germany, which introduced obligatory legislation with a transition period for compliance, with the existing installation ending by Spring 1994 and the Netherlands which introduced a voluntary agreement for VOC reduction up to the year 2000 - "KWS 2000" aiming at reduction of VOC's by 50% by year 2000.

The directives relevance for the printing ink industry is given in Annex XI where it says that the emission limit of solvents from printing inks is 50 mg C/m^3 . According to CEPE the emission limit is too low because it is not the aim to get rid of solvents but to keep them as completely as possible in the products.

The two directives that have been discussed so far would indirectly encourage the use of vegetable oil or water based inks as opposed to mineral oil based inks. There is a piece of legislation in the United States however which is much more direct in its encouragement of vegetable oil based inks. This is the Vegetable Ink Printing Act which was introduced in April 1993 by Senators Wellstone, Bond and Grassley et al. There has been an interest in encouraging the greater use of vegetable oils in printing inks for some time now, and indeed many bills to this end have been passed. However the Vegetable Ink Printing Act is the first bill to have been pushed forward (NAPIM, 1993). The Act has now passed the full US Senate and now moves to the House Committee on Government Operations and the House Administration Committee for consideration. According to the bill minimum percentages of vegetable oil must be used in ink for lithographic printing done by federal agencies and contractors. Minimum contents are 40% for new inks, 20% for sheet fed inks, 20% for forms inks and 10% for heat-set inks (Recycled Paper News, 1994).

The total consumption of vegetable oils in lithographic ink accounted for only 0.4% of total US domestic supply of vegetable oils in 1992. It is hoped that with the Vegetable Printing Ink Act the use of vegetable oils, especially soy oil for lithgraphic inks used in commercial markets in future, will increase.