Adhesives and Tapes Designed to be Less Detrimental to Paper Recycling

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PAPER RECYCLING

Paper recycling, which is the reuse of consumer or pre-consumer waste paper, is not a new invention because waste paper was reused in the Thirteenth Century. Not only have technical conditions changed during the centuries, but also the motives for recycling. Early recycling was driven by the fact that there were few raw materials suitable for paper production. Later on, the main driving force was economic, and today it is a mixture of economics and resource conservation.

To continue supporting paper recycling in Europe, among others a European Declaration on Paper Recovery has been adopted by the Confederation of European Paper Industries. It predetermines the following objectives:

- Further reducing the production of waste during all processes in the paper and board life-cycle.
- Further improving the efficient use of raw and auxiliary materials.
- Optimising collection systems by sharing their expertise with those responsible for collecting recovered paper for recycling purposes.
- Better technical and operational as well as environmentally benign solutions by stimulating and supporting research and development.
- Better awareness of paper recycling by informing consumers about their role in closing the paper loop.

The aim for the year 2005 is that at least 56 percent of paper and board products consumed in Europe should be recycled [Fig. 1] [1]. The use of waste paper is very successful in the production of packaging papers sector [Fig. 2]. Not only in Europe but also in many other countries the amount of wastepaper use increases steadily. World-wide, this is expected to increase from about 85 million tons in 1990 to about 188 million tons in 2005 [2]. To reach this aim it is necessary that all those involved in the paper loop, i. e. the paper manufacturers, the paper processors and the paper users design their processes in the way that a later recycling is possible without problems.

Concerning the saving of resources, paper recycling is a impressive example for the idea of “Sustainable Development“ and for the increasing efforts of a more environmental-conscious society that does not want to leave a heritage of waste with regard to civilization. This is a classic example for treating resources as carefully as possible, even the renewable ones. This thought is pushed forward more and more by the legislature: the introduction of the Packaging Ordinance in Germany in 1991 was a decisive step in this direction. On the European level, this thought has been picked by up by the European Directive on Packaging and Packaging Waste

(94/62/EC) since 1994. The aim of this directive is to continue to reduce the amount of packaging waste in Europe by 2006. Through 2001, a 50% reduction of packaging waste was planned, but at the end of 2001 55-70% was proposed as a new target for the year 2006.

THE PAPER RECYCLING PROCESS

The aim of paper recycling is the recovery of cellulose fibres and the production of paper from these recovered cellulose fibres. All other components in waste paper, whether they come from papermaking or from use of paper, must be removed so they do not disturb the recycling process. If we talk about paper recycling, it is necessary to make a distinction between internal and external paper recycling. Internal paper recycling describes the recycling of production waste within a paper mill (pre-consumer waste). In general only a relatively small amount of rejects (with known amount as well as kind of additives) are moved back into the paper production process. Because these plants normally have no lavish sorting machines it is required that the adhesives be water-soluble or re-dispersible so that they can be moved out in this way. Adhesives used for this application can be tested by the European Standard EN 1720 "Adhesives for Paper and Board Packaging and Disposal Sanitary Products Determination of Dispersibility". External recycling is the recycling of external accumulated paper waste (post-consumer waste). The recycling process of external waste paper in the paper mills [Fig. 3] starts with mixing recovered and sorted used papers in a pulper with water and special chemicals. The main non-fibrous components, like plastic, aluminium foils, staples, paper clips, tapes and stable adhesive films are separated from the fibres in the first step. Fibres are progressively cleaned. Modern recycling processes in paper recycling mills today allow to sort out big and compact particles (>0.2 mm) of thermoplastic impurities. In spite of the most modern technology it is not possible to remove water-soluble, dispersed and very tiny particles from the water-loops by sorting. For certain users (e.g., for the production of graphic and hygienic papers), they must be de-inked. Especially persistent dirt and colour particles are dispersed with the so-called hot disperser to the point that they cannot be seen with the eye. Afterwards, the pulp can be pumped to the paper machine, which is usually integrated in the same mill.

IMPURITIES IN RECYCLED FIBRES

If you take a closer look at paper and paper products, you notice that even simple papers and boards do not consist solely of cellulose fibres. They contain many additives that guarantee the particular use properties of the papers. If used paper products get into waste paper and further into paper recycling then all additives get into the paper recycling process, too. All these non-fibrous components can lead to poor quality of the produced paper (specks, holes) and to production process problems (e. g., wet web breaking). To avoid these problems, non-fibrous components should be removed at the highest degree possible.

THERMOPLASTIC IMPURITIES

Due to the wide variety of substances that come into contact with paper during its lifecycle, there are different kinds of impurities. The most infamous of these are the so-called “stickies”. The term “stickies” does not have a precise, generally applicable definition. Despite this, papermakers understand it to mean those tacky substances

contained in the pulp and process water that deposit or attempt to deposit themselves on paper machine felts, cylinders, or rolls. The particles in the produced paper identified as tacky contaminants are also stickies [3].

Thermoplastic particles (stickies) that are large enough to create noticeable effects (sufficient adhesion and cohesion), in principal come into the paper machine in two ways. First the particles are large enough from the start or during the paper recycling process they form agglomerates large enough out of very tiny particles (secondary stickies) that were in a colloidal solution or finely dispersed. In principle, all non-paper components that can form sufficient adhesion and cohesion can be a source of sticky impurities (e. g., resins from wood, coating binders, inkbinders, coatings, impregnation, adhesives) [Fig. 4] and should be sorted out.

CHARACTERIZATION OF IMPURITIES

For the characterization of the impurities which get into paper recycling with the paper products several very different methods were developed over the last years. Basically waste papers are defibrated first, afterwards a stringing process takes place and then the impurities are characterized. Concerning the test method to determine the sticky potential of adhesive applications, different paper institutes have executed extensive surveys in recent years. A number of these surveys have been financed by INGEDE (the International Association of the Deinking Industry), which is a union of all major paper recycling companies producing graphic papers. Many of these tests have been accompanied technically by FEICA, the European Adhesives Association. In addition to the paper institute of the Technical University in Darmstadt (Germany), which has developed a method that has officially been named INGEDE Method Number 12 [Fig. 5] [4], the Centre Technique du Papier (CTP) in Grenoble (France) and the Papiertechnische Stiftung (PTS) in Munich and Heidenau (Germany) have dealt with the subject of stickies from adhesive applications very intensively. All three institutes have developed lab methods to test adhesive applications. CTP and PTS are also able to test these applications on a pilot-plant scale. Due to the different equipment of these institutes different measurement methods were developed over the last years, thus there may be substantial differences concerning defibrating and sorting the samples. Also, the characterization of impurities, which is usually done with picture analysis equipment, is done differently. Although the results of these different measurement methods cannot be compared directly, all methods provide more or less good relative comparisons [5]. Currently the three institutes are trying to find out if a harmonization of test methods is possible.

PACKAGING

Packaging production globally is estimated at US $400 billion and of this consumer packaging is the biggest segment, accounting for some two-thirds of all consumption. The total packaging materials business is expanding gradually with regional differences consistent with GDP growth. The growth in packaging is largely driven by increased demand for consumer packaged goods. Modern packaging is an important component for the storage and distribution of all kinds of products. In addition it also serves as a preservative for food. In industrialized countries, modern food packaging has eliminated almost completely the risk of loss and damage of goods, and attack by bacteria or insects. However, in developing countries the lack of suitable

packaging and logistics results in dramatic losses in goods as well as quality losses. Today packaging is responsible for marketing tasks, too. In modern supermarkets the goods have to sell themselves and the image of a product is decisively formed by its packaging. As surveys have shown, the average customer does not take even three seconds of time to evaluate the products. Thus packaging has to attract his attention in this short period of time and influence the purchase decision positively. Often the attractiveness of the packaging or even the “experienceability“ of a package at the point of sale determines the success of a product. The large quantities of packaging material used annually get into waste circulation relatively fast, in part because they are usually non-durable goods. If we compare the different materials used for packaging [Fig. 6], then paper is one of the most important and thus the recycling of paper, packaging and boards is of special importance.

RECYCLING OF PACKAGING PAPER AND BOARD

In recent years recycling of packaging materials has increased considerably. Due to the fact that there has been a law for approximately ten years now, a substantial amount of packaging material is recycled in Germany [Fig. 7] [6]. Discarded paper and paperboard packaging which gets into waste circulation is an example of external recycling of paper products. While in the past non-fibrous components could easily be washed away by the process water, today this is not possible because of closed water loops. Therefore compare to former times, today screening is the most important process component for removal of non-paper components in the recycling process of packaging paper and board. After defibrating, the pulp is diluted to 4-5 percent solids, then the suspension passes through several successive cleaning systems in which impurities are separated by their density, size or shape. For this purpose, centrifugal cleaners and pressure screens of a limited selectivity are used which indiscriminately separate contaminants as well as fibres. In order to keep stock losses at a minimum, multi-stage or cascade cleaning equipment is normally provided. After that, cleaning is continued by a fine cleaning stage intended to separate residue by size, shape or density. The apparatus used for this purpose resembles the precleaning equipment, but the separator elements have smaller holes or slots. Today, slotted screens with a slot size up to 0.15 mm are considered most effective as far as sticky removal is concerned. Hence, the development of improved screening machines is of great importance. The new filter-basket types, with their optimised geometry of filter sides and modified rotor elements, allow separation of very fine contaminants.

ADHESIVES FOR PAPER PACKAGING

Adhesive and packaging tapes coated with adhesives have been used for a long time in the processing of products made of paper and board. Many of these papers and paperboard-based products are put together with the help of adhesives to form complex finished products. As a consequence of the different requirements in the sector of paper and packaging adhesives there is a large selection of systems that are tailor-made for problem-solving. Today the user can choose between very different systems. For carton closing mainly hot melt adhesives and pressure sensitive adhesives (PSA) packaging tapes [Fig. 8] are used.

PSA - PACKAGING TAPES

In the field of packaging one possible source of thermoplastic impurities is adhesives from PSA packaging tapes used for closing cardboard and corrugated boxes. Packaging tapes are strips that are some centimetres wide, coated with pressure sensitive adhesives that are sticky at room temperature. Most frequently used in the packaging sector are adhesive tapes with a backing consisting of polypropylene film (about 80%). Rarely, adhesive tapes with polyvinyl chloride backing are used. Paper as backing is only used on very rare occasions. Regarding adhesives there are basically three systems that are used for the production of pressure sensitive adhesive packaging tapes: pressure sensitive adhesives based on solvents (about 45%), water-based dispersions (about 25%) and today more and more hot melts, so-called hot melt pressure sensitive adhesives with about 30% market share. The layer thickness of the adhesives on the backing is in the order of magnitude 16 - 25 µm.

PSA - PACKAGING TAPES IN PAPER RECYCLING

If you look at the paper recycling process in detail, you will notice that it is primarily a mechanical process (supported by heat and alkali). In this process one tries to weaken the composite of the cellulose fibres by shredding and beating (mechanical power), so that only single cellulose fibres remain. The mechanical power in pulper or in refining drums is chosen in the way that it allows a fast but careful fibre isolation. As one tries to sort out all non-paper substances as early and as much as possible, it is necessary to minimize the mechanical stress of these materials so they are not torn into small, non-sortable particles. In general in paper bonding and also in the use of tapes it is expected that paper break (fibre tear) occurs when the bonding is destroyed, i. e. that the cohesion of the adhesive film is higher than the cohesion of the papers. Thus adhesive films are easily removable. Whether a tape with its adhesive film is mechanically stable enough to withstand undamaged the paper recycling process, so that it is not torn into small pieces which pass all sorting facilities, depends on its inherent strength (chemical composition), its application (geometry), and on the substrate to which the adhesive is attached. In this respect it is important to discuss the strength of the film in the environment of paper recycling. In water, hydrophobic polymers show much higher strength than hydrophilic polymers. Therefore adhesives based on hydrophobic polymers can be sorted out more easily than adhesives based on hydrophilic polymers.

If we look at pressure sensitive adhesive films on packaging tapes, we can assume that the adhesive films themselves can be not mechanically stable due to their very small layer thickness. On the other hand, base materials are often very mechanically stable. In particular, base materials made of plastics are so stable that they can survive the recycling process as large particles. Pressure sensitive adhesives on packaging tapes, in cases where adhesion (for example by using a primer) to the plastic backing is higher than the adhesion to the board surface, can be sorted out easily in the recycling process with the plastic backing. If adhesion to the board surface is higher than adhesion to the backing, only the backing material is sorted out and the adhesive film is exposed to the mechanical stress of the pulper. As many surveys have shown, it is possible to fix the adhesive to the backing so firmly that the adhesive film sticks completely to the backing of a PSA box sealing tape and thus can be separated quantitatively with the backing. Hence PSA box sealing tape

products utilizing plastic film backing do not appreciably interfere with the corrugated recycling process and need not be removed prior to recycling [7].

Recycling tests [Fig. 9] [8] with BOPP-base material coated with acrylate dispersion show that it is possible to regain 95-100% of the PS tape and adhesive. The adhesive tape with PVC film and solvent-based rubber adhesive also shows a regaining rate of the adhesive tape of 100 percent: the adhesive tape can completely be sorted out. Whereas the packaging tape based on kraft paper with a solvent-based rubber adhesive could also be sorted out 100%, the tape made with kraft paper base and hot melt adhesive was only 75% separable from the suspension in these tests. The paper base material after the pulping process fragmented into small and medium size particles and therefore the separation in the pulper was faulty. Also the adhesive film was not well separable. This result shows that the hot melt adhesive film in this case was not mechanically stable enough without backing material to remain undestroyed passing through the pulper. The reason for this may be that the layer thickness of the solvent-based rubber adhesive could have been higher, but also the softening point of the solvent-based rubber adhesive system could have been higher than the one of the hot melt system. As hot melts in general are non-water-soluble, they usually show excellent separability. It can be assumed that the small thickness of the adhesive layer is decisive here [9]. When using hot melt systems one should see to it that their softening points are as high as possible. Recycling tests are done at elevated temperature (45°C), hence the softening point of the adhesive could be decisive. If we compare the measured values of non-removable sticky quantities of PSA packaging tapes to the requirements of the paper recycling industry [Fig. 10] [10], we can see that even in a critical case with about 25% non-removable stickies the requirement of a value below 30% is fulfilled.

To sum up the results of the tests of the stickies potential of PSA packaging tapes so far, all important parameters for an adhesive application can be determined and thus known. An adhesive application on a PSA packaging tape is especially recycling-friendly when it has the following properties:

1. a film cohesion as high as possible
2. a softening point of the film as high as possible
3. the film should be as hydrophobic as possible
4. the layer thickness of the film should be as high as possible
5. the substrate should be as mechanically-stable as possible

Since all parameters needed for a recycling-friendly design of an adhesive application for PSA packaging tapes are known, today it is easy to launch such products. If a product cannot meet the requirements today, then the cohesion or softening point of the adhesive can be increased, or its hydrophilicity decreased, or the adhesive can be applied in a thicker layer to a more stable backing material. Which of these five possible solutions is chosen depends on the other requirements demanded from the PSA packaging tape in each case.

SUMMARY

In order to save resources and to not pollute the environment the reuse of paper and board was pushed forward during the last decades more and more. Based on the growing environmental awareness of the population, which lead for example to the

environmental conference in Rio in 1992, legislators began to act in this regard, and in many countries waste paper is already the most important raw material for paper production.

Thermoplastic impurities are often a source of problems in the recycling of post-consumer waste paper. In this connection adhesives and PSA packaging tapes are often discussed. If we look at the fact that the strength of adhesive films is basically substantially higher than the strength of papers and cardboard material, we see that packaging adhesives and tapes can be sorted out easily from the paper recycling process, as many tests have confirmed. Tests of adhesive tapes in paper recycling have shown that pressure sensitive adhesive tape products for box sealing that utilize plastic film backing do not appreciably interfere with the paper recycling process and need not be removed prior to recycling. As the vast majority of all packaging tapes have plastic film as basis material, it has to be concluded that packaging tapes do not cause problems in paper recycling.

But also in paper mills there are some things that can be optimised. By the choice of a gentler pulper that treats the defibration of the waste paper and the additives with care, the mechanical stress on adhesive films can be reduced substantially. Also lower temperatures in the pulper can avoid a weakening of the mechanical properties of thermoplastic films so that they are not torn into tiny particles.

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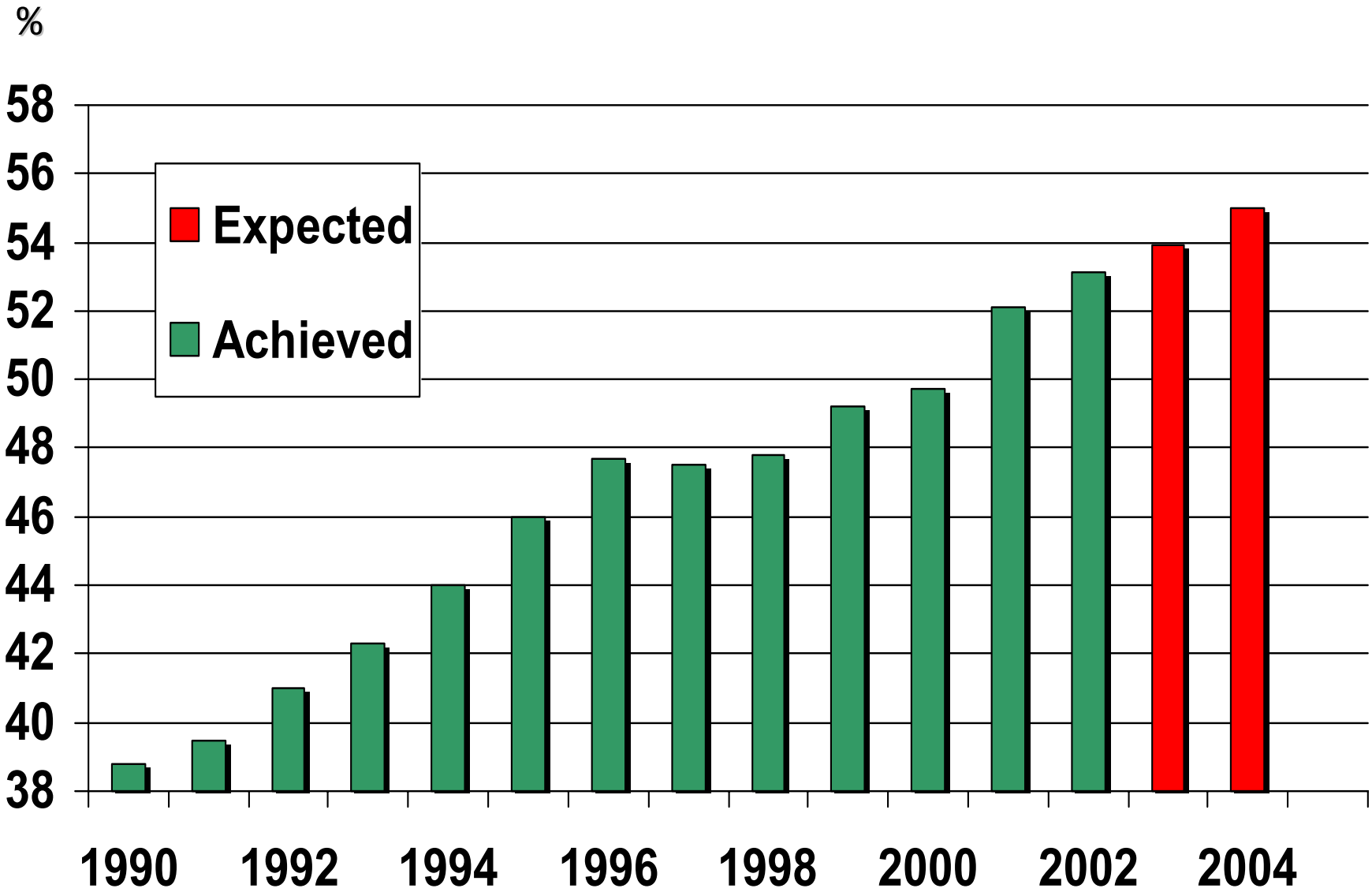

Courtesy of Adhesives.org

Fig. 1 Paper Recycling Rate in Western Europe

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	Production (1,000 tons)	Use of recyled paper (1,000 tons)	Utilisation rate %
Newsprint	10,723	7,426	69.3
Other graphic papers	32,995	2,830	8.6
Total graphic papers	43,718	10,256	23.5
Packaging papers	35,144	26,289	74.8
Household & sanitary	5,400	3,488	64.6
Others	3,941	2,009	51.0
Total	88,203	42,042	47.7

Courtesy of Adhesives.org

Fig. 2 Waste Paper Consumption in Europe

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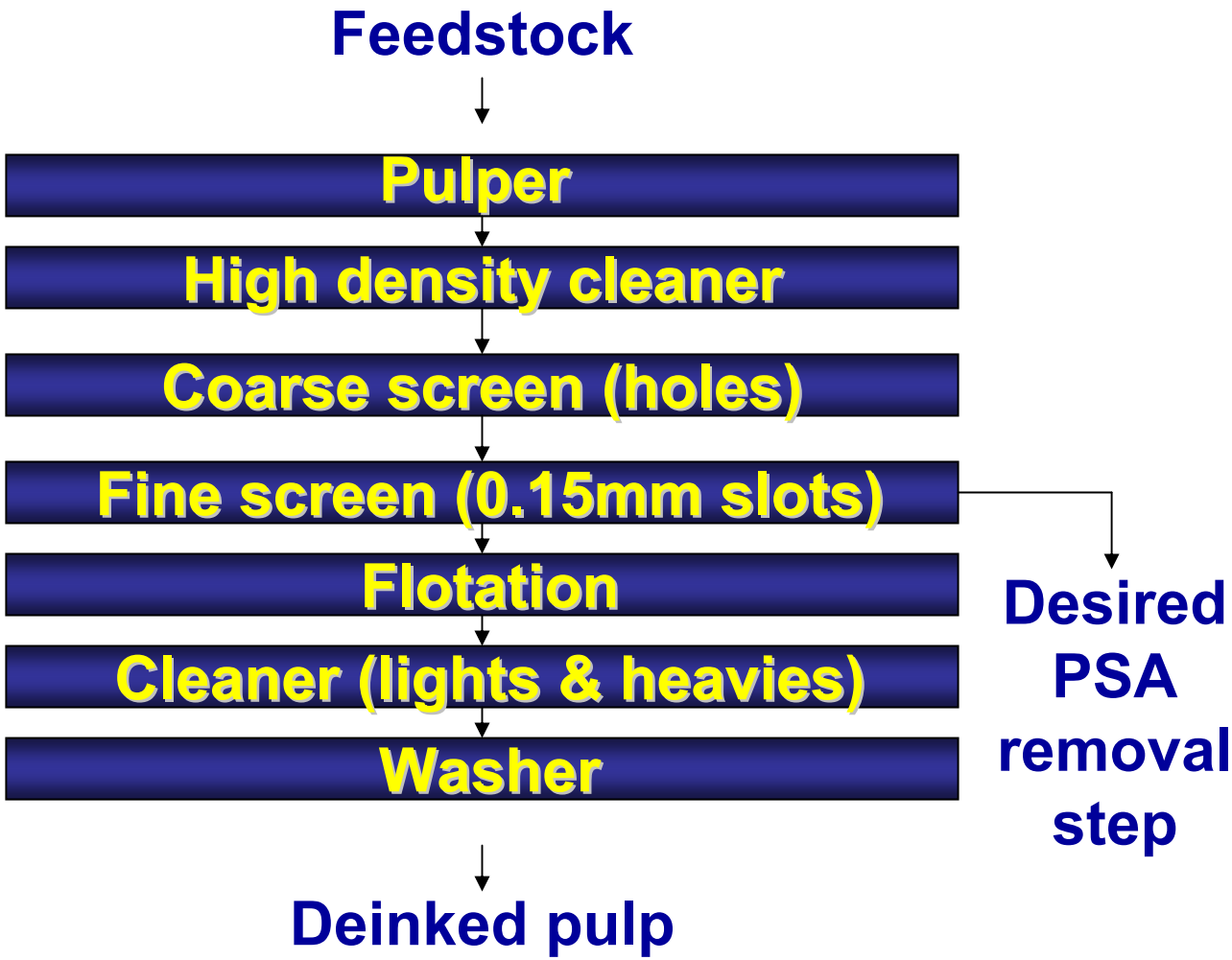

Courtesy of Adhesives.org

Fig. 3 External Paper Recycling Process

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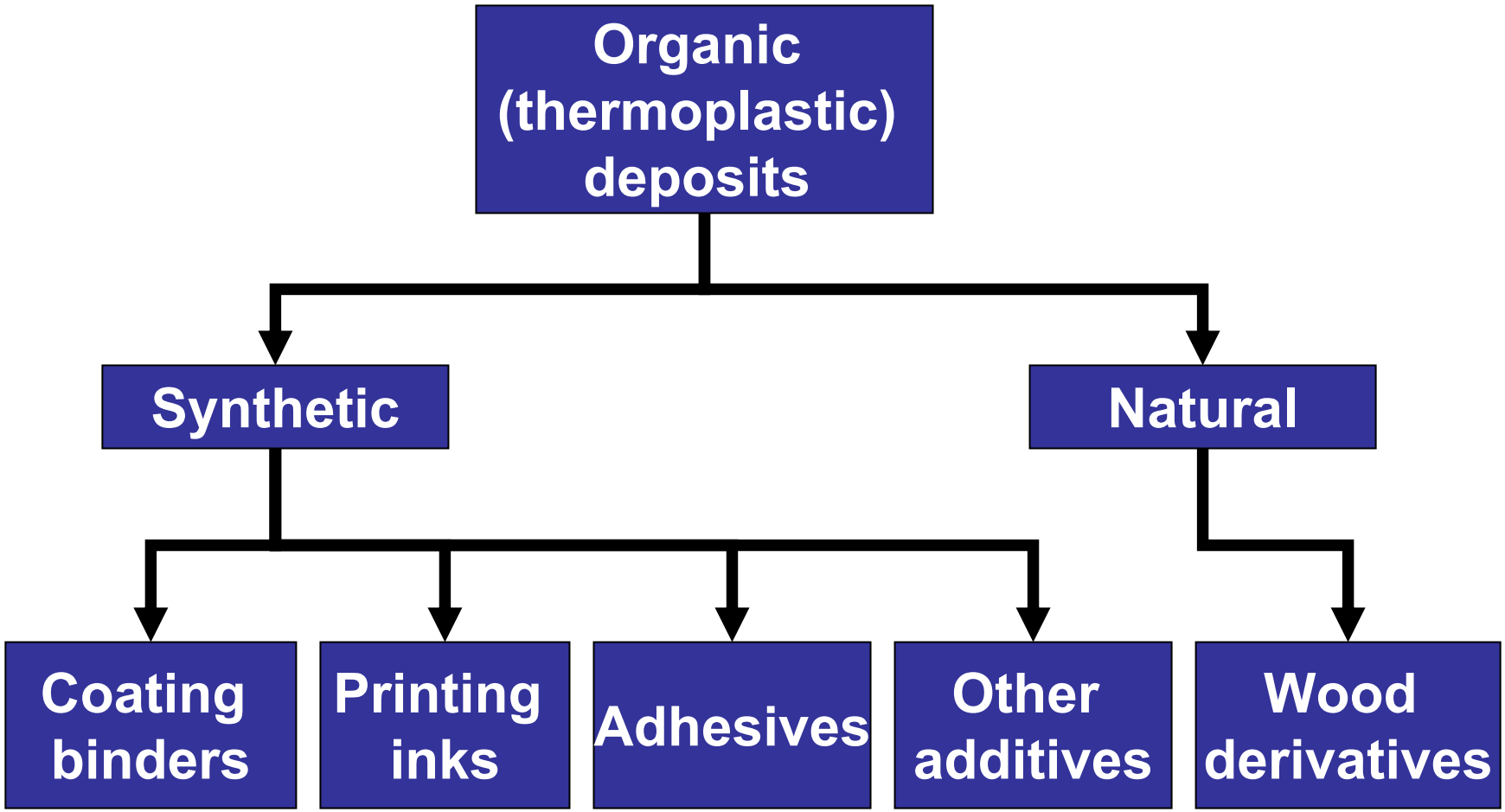


Courtesy of Adhesives.org

Fig. 4 Origins of Thermoplastic Impurities

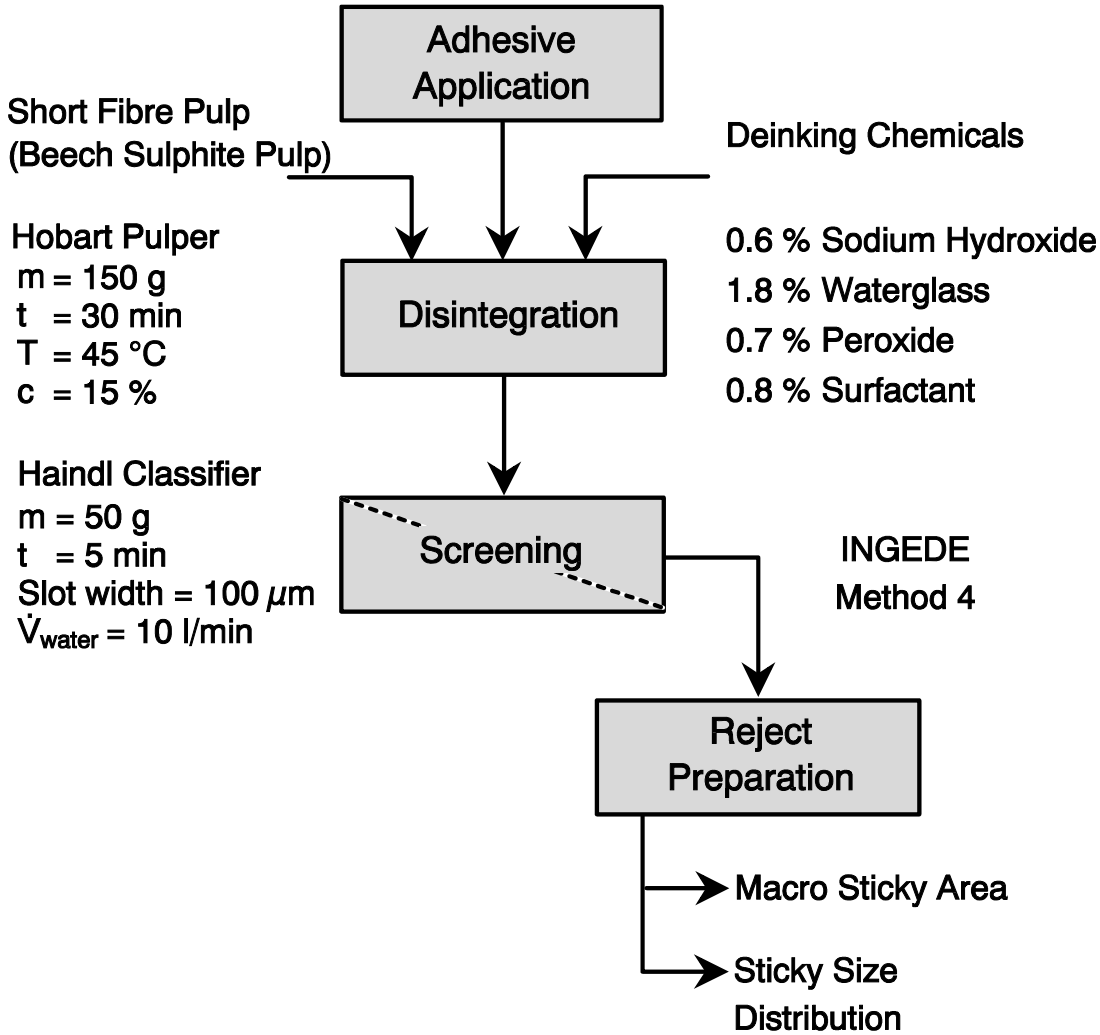
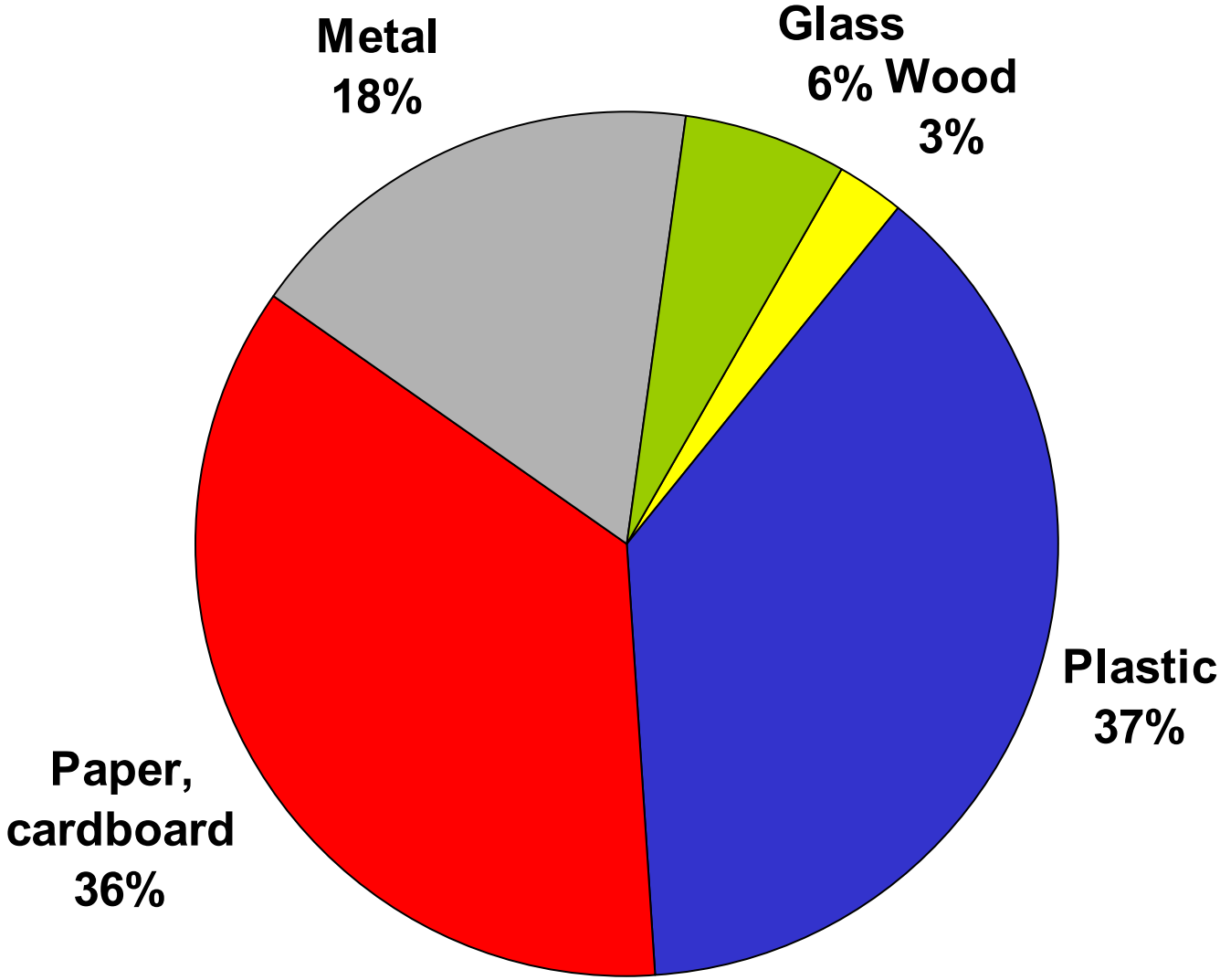


Fig. 5 Sticky Potential Test (INGEDE Method 12)



Courtesy of Adhesives.org

Fig. 6 Packaging Production by Material (2001)

The „Grüne Punkt“ has recycled the following quantities in 2002:	
Glass	2,510,000 tons
Paper, paperboard	1,440,000 tons
Plastics	642,000 tons
Tin plate	315,000 tons
Aluminium	41,000 tons
Composite	379,000 tons

Courtesy of Adhesives.org

Fig. 7 Packaging Recycling in Germany

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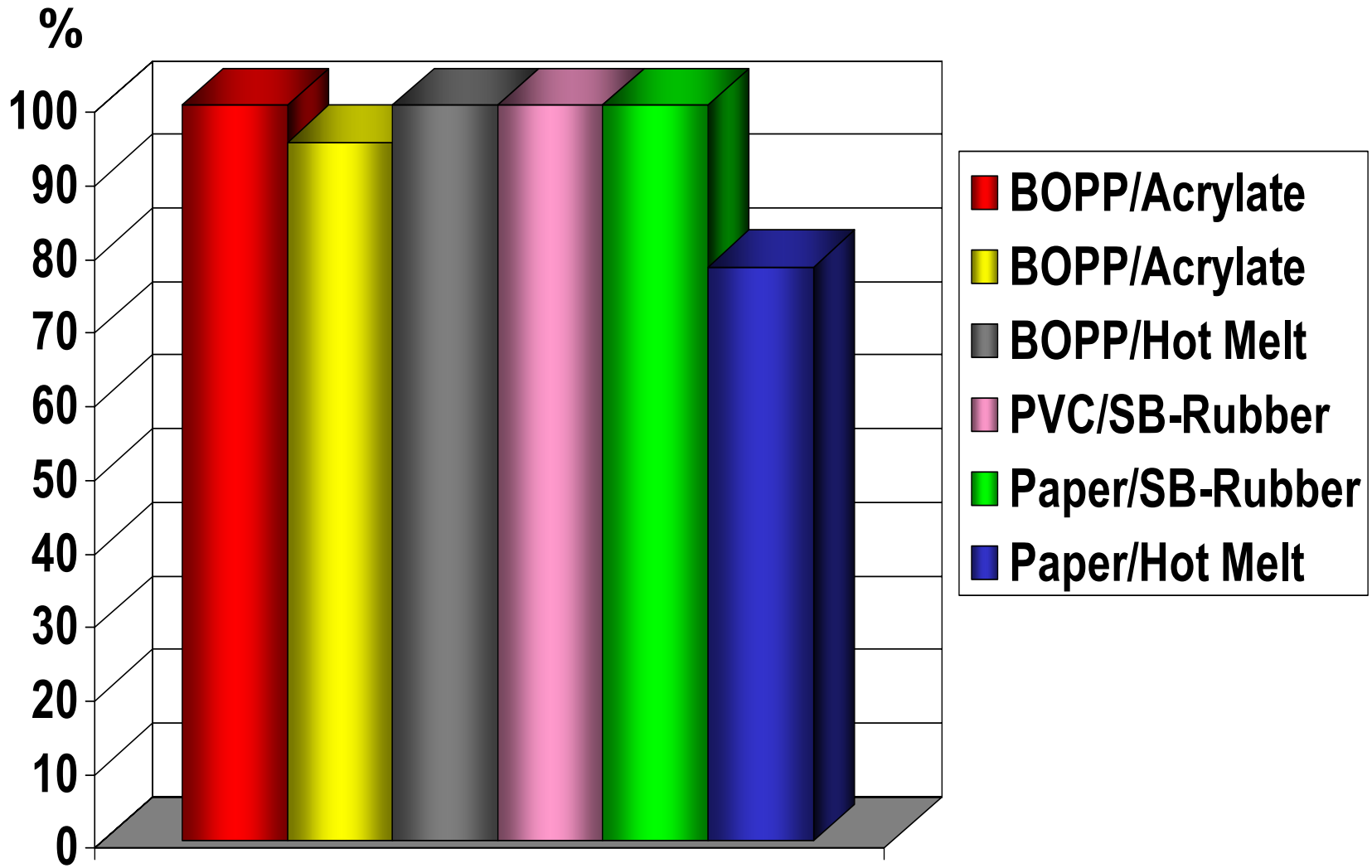
Courtesy of Adhesives.org

Fig. 8 Carton Closing with Packaging Tapes



Courtesy of Adhesives.org

Fig. 9 Separation of Packaging Tapes

Objective	Evaluation parameter	Requirements
Good separability of stickies	Share of sticky surface Ø < 2,000 µm, %	≥ 0 to ≤ 30 %
Low sticky content in Accept	Sticky surface Ø < 2,000 µm, mm²	≤ 4,000 mm²/kg

→ Evaluation of total residues of a lab sorting with 100 µm slots

Fig. 10 Sticky Potential - Technical Specification