A Submission To:

The Committee on

Energy and Natural Resources

114th Maine Legislature

House Chairman: Michael Michaud
Senate chairman: Judy Kany

By:
PCL & Eastern Packaging Limited
May, 1989

INTRODUCTION

To achieve solid waste management objectives in Maine, L.D. 1102 has focused on the impact of retail carryout bags in the state's waste stream. At the heart of the bill, source reduction and recycling are cited as key components of the proposed legislation.

This submission is intended to provide facts related to specific aspects of L.D.1102. The submission will look at the impact of carryout bags in an integrated waste management system, such as that employed in Maine, namely:

- SOURCE REDUCTION
- WASTE-TO-ENERGY INCINERATION
- LANDFILLING
- RECYCLING

Implicit in L.D.1102 is an assumption that paper carryout bags provide some unspecified environmental advantage over plastic carryout bags. This assumption is incorrect and, in this regard, the submission presents relevant facts which clearly show the significant advantage through the use of plastic carryout bags.

Our opposition to this bill is not with the bill's intended objectives nor with the concept of plastics recycling as an important element in solid waste management. Rather, our opposition is with the specifics of the bill that would, in fact, render the objectives as unattainable.

PCL & Eastern Packaging Ltd. feels that enactment of L.D.1102 would be counter productive on environmental grounds. It is the company's hope that this submission will facilitate the committee's requirement for information regarding plastic carryout bags in the waste stream and also insight into the challenges of a manufacturer and a recycler of plastics.

PCL & Eastern shares a common objective with all Mainers in its desire to find solutions to the state's solid waste management problems. As responsible manufacturers and experienced recyclers we hope to become a part of that solution. L.D.1102 will not facilitate the achievement of the objectives.

BAG USAGE IN MAINE INDUSTRY ESTIMATE

Although no "official" statistics are kept by industry or government, it is possible to put together reasonable estimates from known sales and market information. The following data has been prepared by PCL & Eastern Packaging Limited.

ANNUAL USAGE

	NO. OF BAGS
PLASTIC BAGS - NON FOOD RETAILERS	52 MILLION
PLASTIC BAGS - FOOD RETAILERS	80 MILLION
PAPER BAGS - NON FOOD RETAILERS	81 MILLION
PAPER BAGS - FOOD RETAILERS	120 MILLION

	UNITS	LBS.
TOTAL ALL PLASTIC BAGS =	132 MILLION/YEAR	2,640,000
TOTAL ALL PAPER BAGS =	201 MILLION/YEAR	9,045,000

PER CAPITA*	UNITS	LBS.
ANNUAL USAGE-PLASTIC BAGS	103.5 BAGS/YEAR	2.07
PER CAPITA* ANNUAL USAGE-PAPER BAGS	157.6 BAGS/YEAR	7.09

*BASED ON MAINE POPULATION ESTIMATE OF 1,275,000

SOURCE: PCL & EASTERN PACKAGING LIMITED -- ESTIMATES

SOURCE REDUCTION

A key objective of L.D.1102 is the reduction of solid waste entering the State's waste management facilities.

FIG. 1 shows the percentage of plastics in the waste stream.

It has been estimated by the Environmental Protection Agency that 33% of the total waste stream is made up of packaging of various types of materials.

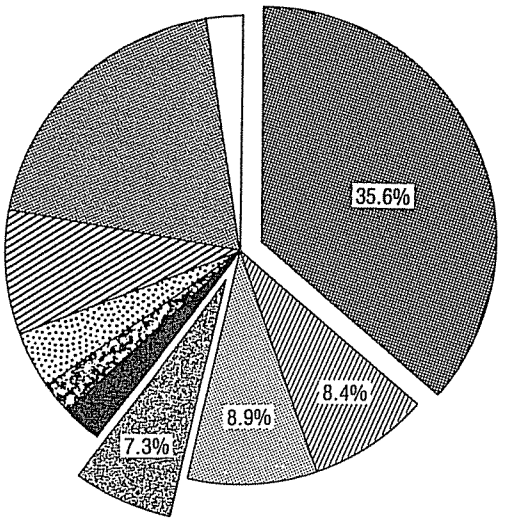


Figure 1

What's in MSW?

- Paper/Paperboard
- Glass
- Metals
- Plastics
- Rubber/Leather
- Textiles
- Wood
- Other
- Food Wastes
- Yard Wastes
- Misc.

Source: Council for Solid Waste Solutions

FIG. 2 shows that of all the Packaging materials in the Municipal Solid Waste, only 11.5% of that amount is plastic. L.D.1102 incorrectly states that plastic packaging comprises 11.5% of all MSW.

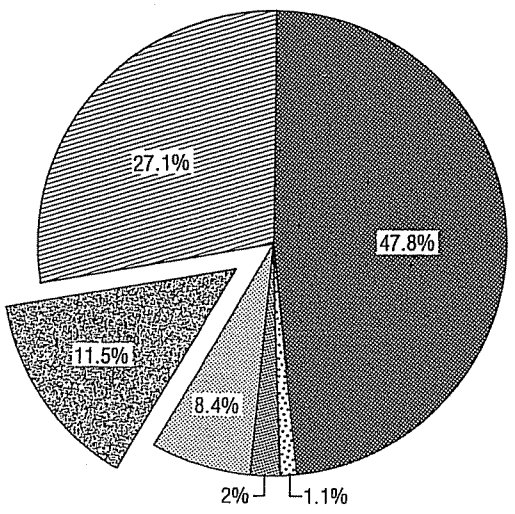


Figure 2

Packaging Materials in MSW, 1984

- Paper
- Wood & Other
- Aluminum
- Steel
- Plastics
- Glass

Source: Franklyn Associates Ltd. September 1984

FIG. 3 This chart shows the correct number that should have been used. Plastic Packaging including bottles, pouches, fast food containers and plastic bags represent 4% of the total MSW.

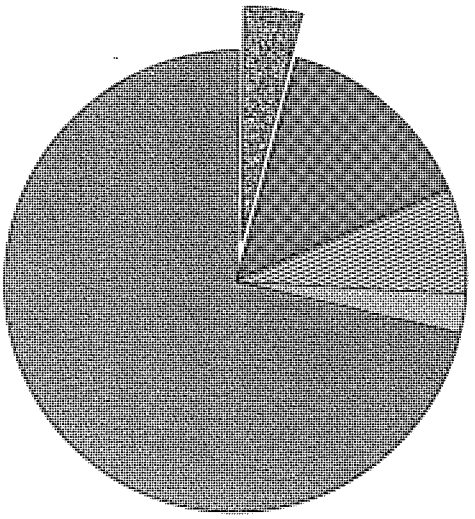


Figure 3

Plastic Containers/Packaging = 4% of MSW

- Plastics
- Paper & Paperboard
- Glass
- Metal
- Other Discards

Source: Council for Solid Waste Solutions

FIG. 4 To isolate plastic bottles and fast food containers from plastic films and bags. About 1/4 of plastic films are used in the manufacture of plastic carryout bags.

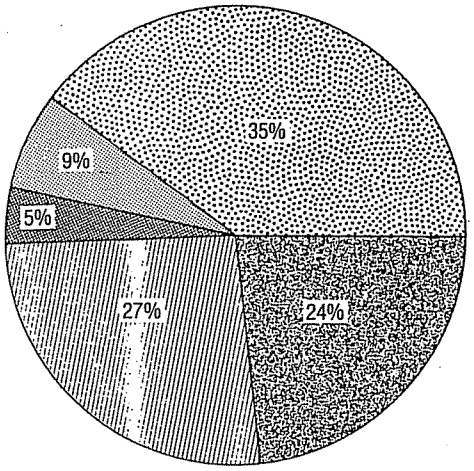


Figure 4

Plastics in Industrial, Institutional and Consumer Packaging

- Films
- Containers
- Bottles
- Closures
- Coatings

Source: Modern Plastics January, 1987

The U.S. Environmental Protection Agency has defined source reduction as "the design and manufacture of products and packaging with minimum toxic content, minimum volume of material, and/or a longer useful life."

The concept of source reduction is perhaps nowhere else more dramatically illustrated than it is between paper bags and plastic bags.

Plastic bags weigh less and occupy 1/6 the volume of paper bags of equivalent carrying capacity.

L.D.1102 which would provide for automatic provision of paper bags would have the effect of increasing the volume of the waste stream by a factor of 6!

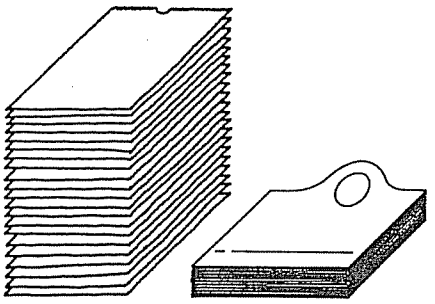


FIG.5

Paper bags are 6 times bulkier than equivalent sized plastic bags. As a consequence, paper bags add considerably to the MSW burden.

WASTE TO ENERGY INCINERATORS

L.D.1102 has overlooked a very important aspect of Maine's integrated solid waste management system --- namely the State's heavy reliance on waste to energy incinerators.

During 1988, two new incinerators were added to the 3 existing facilities. By January, 1989, approximately 65% of Maine's trash was incinerated in the 5 facilities.

Plastic bags are an ideal material for waste to energy incinerators. Made of polyethylene, the bags have a high fuel value and, when incinerated, generate little or no ash and gas by-products of carbon dioxide and water vapor. Becuase plastic bags represent only 1/6 the bulk of paper bags, they relieve the demand on these expensive facilities and at the same time provide a high fuel efficiency.

The chart below shows the Energy Values of a variety of items currently being processed in Maine's incinerators. Polyethylene plastic bags at 19,900 BTU/POUND compared very favorably to Paper bags at 7,000 BTU/POUND.

ENERGY CONTRIBUTIONS OF VARIOUS COMBUSTIBLE MATERIALS IN THE MUNICIPAL SOLID WASTE (MSW) STREAM

MATERIAL	BTU/POUND
PLASTIC BAG (POLYETHYLENE)	19,900
PAPER BAG	7,000
POLYSTYRENE	17,800
RUBBER	10,900
NEWSPAPER	8,000
CORRUGATED BOXES	7,000
TEXTILES	6,900
WOOD	6,700
YARD WASTE	3,000
FOOD WASTE	2,600

By comparison,
the heat content of common fuel is:

RESIDENTIAL FUEL OIL	20,900
WYOMING COAL	9,600

THE PRODUCT-DEVELOPMENT CHALLENGE

During the past 9 months, Maine's solid waste management system has changed dramatically. Manufacturers of products which will ultimately end up in the waste stream have had to monitor this rapidly changing situation to ensure their products are "optimum" from an environmental point of view.

Prior to July 1988 (See MAP "A") 84% of Maine's solid waste was landfilled with only 16% being incinerated. At that time only one of the State's 3 incinerators derived energy from the incineration of trash.

By January, 1989, (See MAP "B") new waste-to-energy incinerators had been constructed in South Portland and Orrington with another proposed for Lewiston. As of January, 1989, only 35% of the State's trash was being landfilled.

To ensure environmentally sound products, PCL & Eastern Packaging has monitored these changes closely. In addition to new facilities, the State of Maine has introduced "Maine Recycles" and, as a result, several communities have responded with recycling programs.

This rapid change has meant product development programs have also been modified.

1). Biodegradability now has reduced importance since most MSW is being incinerated.

2). Products that burn clean and with little or no bottom ash have increased in importance in Maine.

3). Generally speaking smaller, rural communities still rely on landfill technology. Landfill sites in these areas do not "foster" biodegradability and are managed to achieve sanitary objectives rather than to promote biological activity necessary for any material to biodegrade.

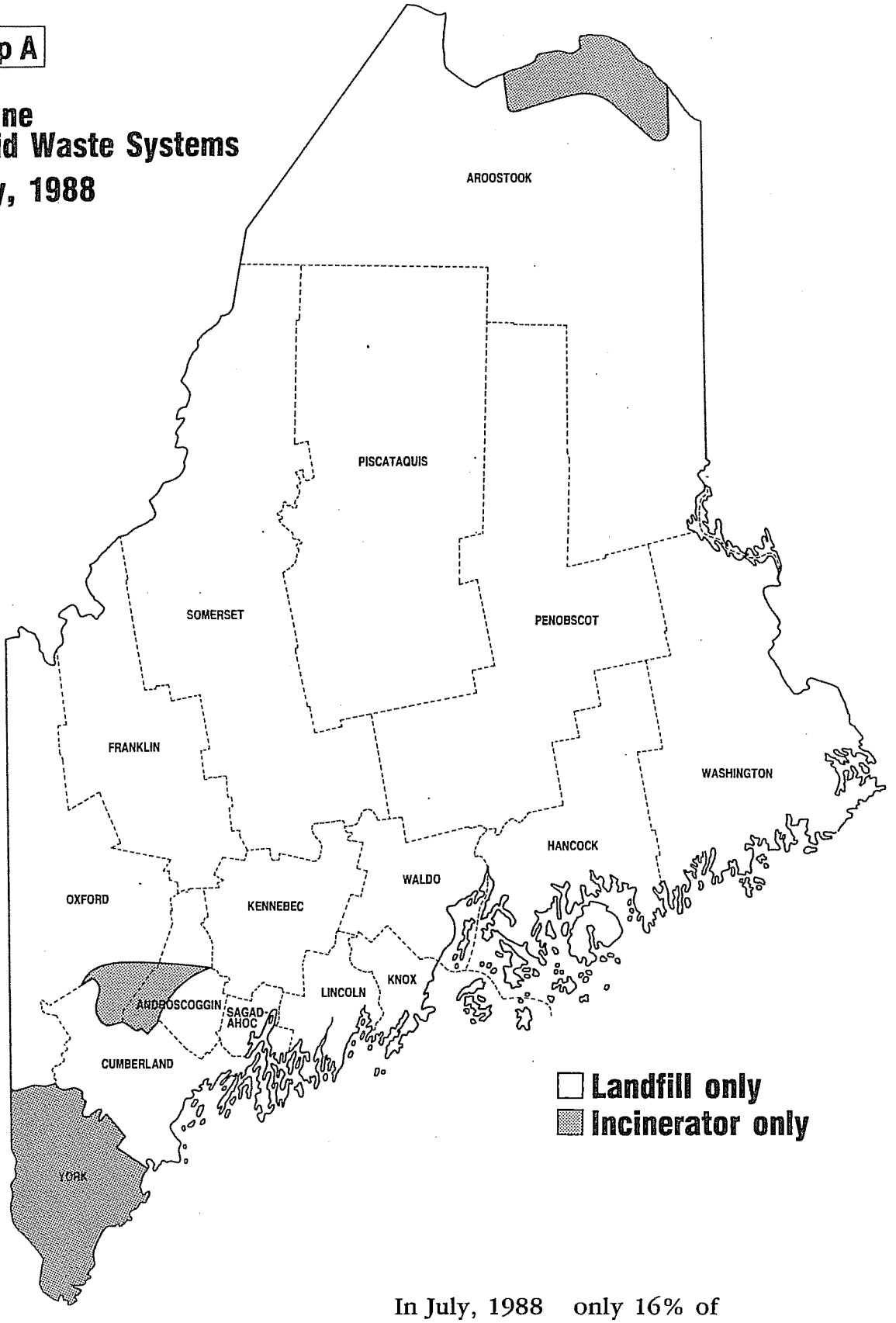
4). Manufacturers and retailers should be mindful that -- more than ever before -- solid waste solutions in Maine are "site specific".

5). In all areas of Maine, source reduction has assumed increased importance.

1988 and 1989 has been a year of challenges for all manufacturers who must monitor a rapidly changing situation and then try to anticipate community needs in their product development programs.

Map A

Maine
Solid Waste Systems
July, 1988

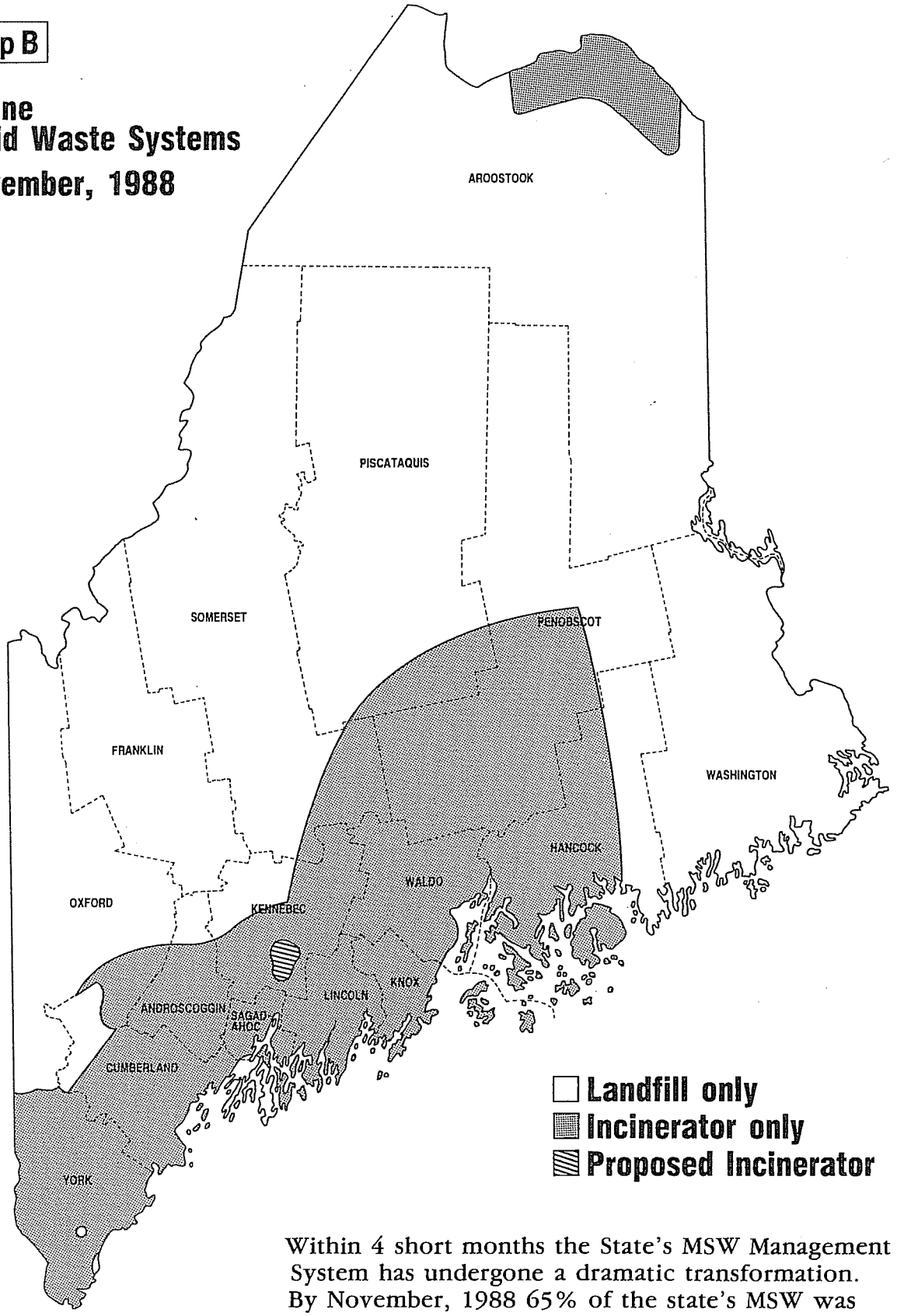


In July, 1988 only 16% of Maine's MSW was incinerated.

SOURCE: PCL & Eastern Packaging Limited survey.

Map B

Maine
Solid Waste Systems
November, 1988



Within 4 short months the State's MSW Management System has undergone a dramatic transformation. By November, 1988 65% of the state's MSW was incinerated. This transformation has had significant impact on Manufacturers' product development programs.

SOURCE: PCL & Eastern Packaging Limited survey.

LANDFILLS

As mentioned, landfills in the State now process only 35% of all MSW. Should the proposed incinerator at Lewiston be approved, this percentage would fall even lower.

PCL & Eastern Packaging recognizes that as landfill reliance declines in the years ahead, the need for its line of biodegradable carryout bags will also decline. It should be remembered that biodegradable plastic bags were first introduced in Maine at a time when 84% of Maine's communities relied on landfill.

Because carryout bags represent less than 1% of MSW and that, in Maine, 65% of MSW is incinerated, biodegradable plastic bags represent only a sliver of the total MSW solution. The challenge is magnified when it is known that local management of smaller landfill does little to foster the conditions necessary for biological activity. In fact, biodegradability of any material is difficult to achieve.

BIODEGRADABLE PLASTICS USING MODIFIED STARCH MATERIALS

An additive containing corn starch 6% and soya oil 1% is added to conventional polyethylene during extrusion.

When buried, immersed in sea water or fresh water, micro-organisms already present at the site consume the starch leaving a highly porous plastic material. With the starch removed, the surface area of the plastic film is greatly increased --- a key element in the second mechanism.

In the second phase, the soya oil (an auto-oxidant) combines with the mineral salts in the soil to create per-oxides which are necessary for oxidation to occur. The combined effect of increased surface area and oxidation causes the accelerated degradation of the material. This mechanism continues until the remaining particles are themselves metabolized by micro-organisms at the site.

Because Polyethylene is comprised of nothing more than Carbon and Hydrogen and the oxygen that has been created the by-products of this degradation are Carbon Dioxide and Water.

The conditions necessary for biodegradation to occur are identical in all respects to the conditions necessary for any material to degrade:

1). Suitable PH level
2). Presence of Micro organisms
3). Temperature
4). Thickness of material
5). Presence of mineral salts

The additive is made available by two companies in North America --- Archer Daniels Midland and St. Lawrence Starch. Effectiveness of the additives have been demonstrated in a number of independent studies by Universities and Government Departments including: U.S. Department of Agriculture; University of Missouri; University of Surrey (England) and Brunel University (England). (See Appendix "B")

Items that are normally thought of as "biodegradable" such as Paper bags require the presence of oxygen during the entire process. However the starch additive --- because it provides an auto-oxidant has been demonstrated to be effective even in anaerobic conditions. This phenomenum was recently revealed in a published study by the University of Missouri at an American Chemical Society meeting in April, 1989.

In many of Maine's smaller landfills where biodegradability is not being nurtured, the addition of an auto oxidant represents a significant breakthrough.

RECYCLABILITY OF BIODEGRADABLE PLASTIC BAGS

PCL & Eastern Packaging currently recycles biodegradable plastic factory waste and utilizes the material in the production of biodegradable plastic trash bags. However, the company realizes that commercial applications of this material are limited. The products are intended for use in communities in which no recycling is being undertaken and in which landfill technology is in use. Retailers operating in communities intending to recycle plastic bags will likely wish to consider conventional plastics.

RECYCLING

All PCL plants are active recyclers of factory-produced plastic waste. It is interesting to note that PCL's parent company was actually established because it had developed recycling capability in 1972 and, as a result, was able to achieve competitive advantage that enabled it to enter the infant plastic carrier sack industry.

Plastic carryout bags are 100% recyclable in their present form. The Equipment necessary to recycle this plastic is commonly available. The equipment is, however, quite expensive (minimum investment $500,000) and not labor intensive (3 men could recycle 70% of all the plastic bags used in Maine).

There are several factors, however, that should be known when considering L.D.1102.

1). Competing Uses: Many householders use plastic bags under the sink as a kitchen catcher for coffee grounds, potato peels, bacon drippings etc etc. These bags are ideal for this purpose because they are water proof and will not weaken or break when wet substances are added.

A potential recycler may have difficulty in getting householders to give up this second use and would likely recover only a small fraction of the bags available. Community-minded householders prepared to cooperate with a recycling effort may, in fact, return the free carryout bags but replace them with purchased kitchen catchers. The result would be no net benefit to the environment as a purchased polyethylene kitchen catcher would be added to the waste stream in place of the polyethylene carryout bag.

2). Community Collection Programs: At the present time Mainers use plastic carryout bags at the rate of 2.07 lbs.per year. Would recycling collection contractors be prepared to make the physical adjustment necessary (adding another section to their vehicles) for an item so little used in Maine?

3). Other Plastics: If a company such as PCL & Eastern were prepared to make the required investment, is it not likely that other legislation involving plastics recycling will not follow? If other plastics are also recovered the co-mingling option may be preferable, and thereby eliminate the product-specific collection effort related to plastic bags. The life of the plastic bags recycling operation may be very short-lived despite its high capital cost.

4). It may be preferable for Maine to priorize its plastic recycling agenda to ensure that it does not inadvertently deprive itself of a more comprehensive plastics recycling iniative with more likelihood of achieving the State's recycling targets. Under L.D.1102 the Co-mingling option, for instance, would be less attainable.

5). L.D.1102, on the one hand, discourages the use of plastic bags, despite significant environmental advantages including recycling capability and, on the other hand, by encouraging the use of paper bags reduces the incentive for a plastic bag manufacturer to invest in any environmentally sound projects. L.D.1102 ironically would increase the volume of the waste stream and at the same time reduce the chances of any real recycling effort.

OTHER FACTORS FOR CONSIDERATION

1). ECONOMIC: Unbleached KRAFT Paper the material used in the vast majority of paper bags is not manufactured in the State of Maine. L.D.1102 would have no impact on the economy of Maine as it relates to paper production.

Polyethylene Resin or Film is also not manufactured in Maine and similarly would not suffer or benefit under L.D.1102.

Retailers in Maine, however, would suffer economically since Kraft bags are significantly more expensive than their plastic counterpart.

If plastic bags were not in use in Maine, and were replaced by Paper, the lost fuel value at waste to energy plants would be sufficient to heat 172 Maine residences for a 12 month period.

2). OTHER ENVIRONMENTAL FACTORS: Faced with a similar solid waste management problem, the West German Government recently completed a detailed study in which the environmental impact of plastic bags vs. paper bags was examined. The study examined the environmental impact at every stage of manufacturer and concluded at the MSW stage. The results were very revealing and worthy of mention in this submission. (See Appendix "A")

The study, of course, looked at the processes from a West German perspective and as a result not all of the findings could be appropriate in the Maine experience. For example, the study mentioned that older incinerators might not be capable of utilizing the high BTU benefits of plastic bags. While this was true in West Germany, the newer incinerator plants in Maine are not constrained in this manner.

Also, during the production of polyethylene resin, the study revealed low levels of SO_2 emissions into the air. In North America, however, "Sweet Crude" is used with no sulphur content and, hence, no SO_2 emissions.

Similar differences may also be present as it pertains to paper bag production and, if so, they should be recognized.

The summary of the West German Study is shown below. (From Table 22, page 38)

ENVIRONMENTAL DAMAGE FROM
THE MANUFACTURE OF 50,000 CARRIER BAGS

AIR POLLUTING EMISSIONS	POLY-ETHYLENE BAGS	KRAFT PAPER UNBLEACHED	PAPER COMBINATIONS
SO_2 (Sulphur Dioxide)	9.9 kg	19.4 kg	28.1 kg
NOX (Nitrous Oxide)	6.8 kg	10.2 kg	10.8 kg
CH (Organic Substances)	3.8 kg	1.2 kg	1.5 kg
CO (Carbon Monoxide)	1.0 kg	3.0 kg	6.4 kg
DUST	.5 kg	3.2 kg	3.8 kg
WASTE WATER POLLUTION			
CSB (Chemical Oxygen Demand)	.5 kg	16.4 kg	107.8 kg
BSB_5 (Biochemical Oxygen Demand)	.5 kg	9.2 kg	43.1 kg
CH (Organic)	.003 kg	N/A	N/A
PHENOL	.0001 kg	N/A	N/A
AOX (Chlorganic Compounds)	N/A	N/A	5.0 kg

SOURCE: West German Dept. of Environment - August, 1988.

CONCLUSIONS & RECOMMENDATIONS

1). Both Plastic Bags and Paper Bags contribute to Maine's MSW and, as such, are part of the Solid Waste problem.

2). Recycling obligations should not be focused only on plastic bags but, rather, both plastic bags and paper bags.

3). Plastic recycling objectives should be considered "Collectively". In this way collection can be facilitated and new investment in recycling can be more "solution oriented".

4). Legislation involving recycling of individual plastic products may fragment the plastic recycling effort and inadvertently deprive the State of more comprehensive plastic recycling opportunities.

5). Maine should establish a Plastics Recycling Advisory Board comprised of people knowledgeable in plastics, environment and MSW. Recommendations of this board could concentrate the plastic recycling effort in Maine into one cohesive effort.

6). While the objectives of L.D.1102 are achievable, the specific elements of the bill are not workable and even counter productive.

7). L.D.1102 implies that paper carryout bags are environmentally advantageous. This is not borne out by the facts. In virtually all relevant categories, plastic bags are environmentally advantageous.

Appendix "A"

Comparison of The Effects on The Environment from Polyethylene and Paper Carrier Bags

Published by:
Federal Office of The Environment
Federal Republic of Germany (West Germany)
Bismarck Platz 1, 1000 Berlin 3
August, 1988

By:
PCL & Eastern Packaging Limited
May, 1989

COMPARISON OF THE EFFECTS ON THE ENVIRONMENT FROM POLYETHYLENE AND PAPER CARRIER BAGS

Publisher: Federal Office of the Environment
Bismarckplatz 1
1000 BERLIN 33

Tel: 030/8903-1
Telex: 183 756

Editing: Specialised Area II 2.4
Dr Wolfgang Pllehn

Berlin, August 1988

PREFACE

The comparative assessment of damage to the environment from differing substances with specific effects in individual environmental media is always problematic. It requires weighing up social, ethical and aesthetic values, for which no generally valid and recognised standards of comparison exist. In principle, for a scientifically comprehensible comparison, only criteria can be used which can be recorded rationally. Other aspects of the complex system, the environment, such as for example, questions of aesthetics, of social acceptance, or of pedagogic symbolic content, cannot be taken into consideration very often, owing to a lack of objectiveness.

Nonetheless, in special cases, damages to the environment caused by man can be made comparable to the extent that the correct decision, from the ecological point of view, is obvious. In the area of production, there are examples of this, such as asbestos or fluorochloro hydrocarbons for which the negative ecological effects of a substance become so clearly evident that measures including bans, or at least restrictions on application, are justified.

On the other hand, in most technological processes and products, it is not obvious which of the variants in the sum total leads to more-or-less ecological damage. Particularly, where the quantity of production is high, such assessments are meaningful. Consequently, ecological comparisons are necessary, even if they are full of difficulties.

In the comparison between polyethylene and paper carrier bags, no doubt the impression which existed among the public was that polyethylene had ecological disadvantages compared with paper. This led some communities and institutions to change from polyethylene to paper carrier bags for ecological reasons. We have taken enquiries relating to this, which were put to the Federal Office of the Environment as an opportunity to ascertain the effects on the environment produced by these two products and to compare them with each other. A first draft was worked out in 1986 and has been discussed widely and controversially since then. The new aspects and information presented, particularly by the manufacturers, have some influence on the report at hand. This report is intended to provide a basis for the assessment of effects on the environment in this special area of the nature of packaging. The conclusions of the comparison cannot necessarily be applied to other products made of polyethylene.

As a rule, both the polyethylene carrier bag and the paper carrier bag are used only once. Also, in order to show alternatives to the use of these throw-away products which would do justice to the problem of high quantities of waste, as well as the problem of inadequate possibilities of re-using the substances from plastics in domestic refuse, the environmental effects from the traditional shopping bag have been estimated. This example confirms the result which is actually self-evident: Any relief of the strain on the environment worth mentioning is only achieved when a carrier bag is used which can be used repeatedly, whether it is made of natural fibres such as jute or of synthetic fibres such as polyamide.

Dr. Heinrich von Lersner
President of the Federal Office of the Environment

CONTENTS

1. INTRODUCTION

Owing to the large quantities of waste it causes, packaging has presented a publically discussed environmental problem for some time. Carrier bags offered in supermarkets, as well as other places, are also throw-away products, whose quantity should be kept to a minimum. Plastics in particular and, therefore, also plastic carrier bags, are regarded as a symbol of the negative influence on the environment from industrial production and the use of industrial products. This little differentiated assessment has led, on several occasions, to the demand to replace polyethylene carrier bags with paper carrier bags. Thus, in Italy recently, the measures against plastic carrier bags went as far as banning their use. In the foreground of this decision, was the fact that trippers were leaving large numbers of carrier bags behind on the beaches where they were ruining the landscape because of their high durability.

The ecological effects relating to carrier bags are compared in the following comparison of paper and polyethylene carrier bags. The pollution of air and water during manufacture and processing, as well as waste management, energy consumption, protection of resources and the possibilities of recycling, are taken into consideration.

The result of the comparison represents the current situation 1986/87. The implementation of various measures to protect the environment (e.g. T A Luft and the Ordinance Governing Large Incinerators) will lead generally to a reduction of emissions. In all probability, this will not have any effect relevant to the results.

2. BASIS AND LIMITS OF THE COMPARISON

Within the framework of this comparison, carrier bags for shopping are compared which have the same suitability for use, such as those offered in the retail trade of groceries and in supermarkets. With a volume of 12 litre, they are able to take a load of 5 kg.

2.1. Material Prerequisites

Plastic carrier bags are manufactured almost entirely from polyethylene. At the same time, the portion of low-density polyethylene (LDPE, film gauge as rule approximately 50 μm) is predominant. In addition, mixtures of LLDPE (linear low-density polythylene) and HDPE (high-density polyethylene) are put in /1/.

Through the insertion of LLDPE, which has a greater strength compared to LDPE because of its linear molecular structure and the equally stronger HDPE, a reduction of the film gauge is possible. For example, food bags and deep freeze bags, as well as so-called shirt bags and knot bags made of HDPE (10 to 20 μ m) /2/ have a very low film strength, but they will not be considered more closely here.

Paper carrier bags which have a comparably high load-bearing capacity are made predominantly from kraft paper made from a basis of sulphate cellulose (paper weight as a rule 90 g/m^2). However, it is possible for products to be manufactured, at least partially, from corresponding paper made on the basis of sulphite cellulose (then it has a lower strength) /3/.

In principle, the use of recycled raw materials is possible for both polyethylene and paper carrier bags and is also used in practice. However, the amount of polyethylene granules and kraft waste paper is limited.

2.2. Procedure

The comparison begins with obtaining the raw materials, continues through the various manufacturing steps to the finished carrier bag and its use, then on to waste management. The energy consumptions during manufacture, as well as the air-polluting emissions and damages from waste water are ascertained. Apart from the quantity of waste, waste management can only be taken into account quantitatively. In the consideration of the production of cellulose, it is presupposed that the raw material, wood, is used practically completely, i.e., in addition to a high exploitation of cellulose; the residues and waste which occur are used as a source of energy. Consequently, the additional use of fossil fuels and/or electric energy depends on the quantity of wood used and the exploitation of cellulose. The data relating to energy were taken from a study by the Institute for Paper Manufacture, Darmstadt /3/.

During the manufacture of polyethylene from petroleum, a multitude of products occur at individual steps of production, so that it is not possible to ascertain directly what the necessary energy consumption is. The main products and the by-products have to be taken into account. Kindler and Nikles /4,5/ provide a basis for this. They have calculated energy equivalence values for many plastics where "the energy equivalence value is defined as the total expenditure of energy and raw materials which has to be expended to manufacture a product, e.g., a material or a finished part or for the supply of energy" /5/. At the same time, the energetic and material use of raw materials is regarded as equivalent. The procedure for wood, the raw material for the manufacture of paper, is the same. The quantity of wood necessary for the manufacture of cellulose is taken into account in the energy balance with the lower calorific value.

The expenditure of energy for the construction and maintenance of the plants for manufacturing cellulose and paper, and the petro-chemical and plastics producing industry, is not taken into account because it is regarded as small enough to be neglected in comparison with the through-put of production and the energy contained in that.

The calculation of damage to the environment from the manufacture of paper and polyethylene carrier bags results, as a rule, from average values which come as close as possible to the average emission conditions in the Federal Republic of Germany. Consequently, modern plants can undercut the values given. Older plants which no longer correspond with the current level of technology, damage the environment with, in some cases, considerably higher emissions. To the extent that data of this sort is not available, other sources are consulted and discussed comparatively. This is particularly valid for data relating to the manufacture of kraft paper because kraft paper (made from sulphate cellulose) for carrier bags is produced predominantly outside the Federal Republic of Germany. Essentially, the investigation into literature made by the Institute for Paper Manufacture in Darmstadt /3/, which supplement Swedish emission factors with its own investigation, supplies the basis for data here.

The important damages to the environment from the manufacture of paper and polyethylene are ascertained and compared quantitatively. These include among the air-polluting emissions SO_2, NO_x, organic substances (CH), CO and dust; among the waste water introductions the parameters CSB[1] and BSB_5[2], as well as organic (CH, phenols) and chlororganic compounds (AOX).

Other significant emissions, in each case specific to production, are taken into account as well.

2.3. Comparison with Shopping Bags

The damages to the environment from paper and polyethylene carrier bags used only once can really only be evaluated correctly if the normal shopping bags which are used frequently are included in the comparison. Consequently, two shopping bags will also be considered, by way of example, which are comparable in handling and use to paper and polyethylene carrier bags used only once. One is a folding bag made from polyamide fibres which, when folded, takes up little space; the other is a bag made of jute fibres. Both correspond in size to the carrier bags normally used only once under comparison here. It was not possible comprehensively to ascertain the damages to the environment from the production of these shopping bags within the framework of this report. The emissions and the energy necessary for manufacture are calculated approximately and compared with the results for paper and polyethylene carrier bags used only once.

---

1. CSB : Chemical oxygen demand (COD)

2. BSB_5: Biochemical oxygen demand within 5 days. (BOD_5)

3. COMPARISON OF THE ENVIRONMENTAL EFFECTS

The total energy consumption (energy equivalent values) and the environmental damages from the manufacture of, in each case, 50,000 polyethylene and paper carrier bags are calculated in the appendix. The summarised tables 21 and 22 from the appendix are reproduced below. The shopping bags (polyamide folding bag and jute bag) included in the comparison, result in a significantly smaller consumption of energy (see pages 7-9).

G = Giga 10^9

50,000 carrier bags made from	Polyethylene[1])	Kraft Paper[2]) Unbleached	Paper Combinations[2])[3])
Energy			
For the manufacturing process	29 GJ	67 GJ[4])	69 GJ[4])
Contained in material	38 GJ	29 GJ	29 GJ
Total energy consumption	67 GJ	96 GJ	98 GJ
Air Polluting Emissions			
SO_2	9,9 kg	19,4 kg	28,1 kg
NO_x	6,8 kg	10,2 kg	10,8 kg
CH	3,8 kg	1,2 kg	1,5 kg
CO	1,0 kg	3,0 kg	6,4 kg
Dust	0,5 kg	3,2 kg	3,8 kg
Waste Water Pollution			
CSB	0,5 kg	16,4 kg	107,8 kg
BSB_5	0,02 kg	9,2 kg	43,1 kg
CH	0,003 kg	Inapplicable	Inapplicable
Phenols	0,0001 kg	Inapplicable	Inapplicable
AOX[5])	Inapplicable	Inapplicable	5 kg

1) $0.4m^2$ PE-film with a strength of 50 μm (18g)
2) $0.4m^2$ paper with a surface weight of 90 g/m^2 (36g)
3) 60% white kraft paper (made from unbleached sulphate cellulose)
   25% brown kraft paper (made from unbleached sulphate cellulose)
   15% white sulphite paper (made from unbleached sulphite cellulose)

   This combination of paper is given by the Institute for Paper Manufacture for the whole area of the production of carrier bags and packets in the Federal Republic of Germany /3/.

4) The energy consumption for the manufacturing process contains 29 GJ gained from the incineration of residues (waste from treatment etc.). This portion and the material portion came from the raw material wood (58 GJ altogether).

5) Organochlorine Compounds

3.1. Input of Raw Materials and Energy

The raw material basis for polyethylene carrier bags is petroleum. Qualitatively, high value quality wood and waste wood from wood-processing companies are used to manufacture paper[1].

In contrast with petroleum, wood is a raw material which grows again and the use of it is to be evaluated positively in comparison with the use of (limited) fossil fuels.

Independent of this, the amount of wood which can be used in industry is limited, unless over-exploitation of nature is to be carried out. The regenerative production of the raw material wood has to be contrasted with its environmental effects when it is used, which are not unproblematic (e.g. emissions of sawdust) and the manufacture of cellulose which is strongly environmentally damaging.

In the evaluation of the energy consumption for both types of carrier bag, not only the energy for manufacturing will be included in the comparison, but also the energy content in the finished carrier bag. The portion of energy bound in the material of the finished carrier bag comprises about 60% in polyethylene and 30% in paper of the total energy used to manufacture the carrier bag. The energy input for the manufacturing process in the case of paper carrier bags, is 67 GJ and corresponds already with the total energy consumption for the same number of polyethylene carrier bags (primary energy input plus energy content in material). This energy consists of 55% from fossilized fuels and 45% from the energetic use of residues occurring from the manufacture of cellulose, which is thus treated as equivalent to the production of energy from fossil fuels [2].

As a user of the raw materials poor quality wood and waste wood, the production of cellulose stands in competition not only with the chipboard industry, but also with the energetic use of wood which plays a role, not unimportant, in densely wooded regions (compare Pothmann /6/ regarding this). Thus, the aspect of "replaceable raw material (wood)" is to be taken into consideration more from an economic point of view. Essentially, the use as a carrier of energy depends on the price of fossil fuels and will become more interesting as the introductory price rises, e.g. for crude oil. The energy content of the wood used (lower calorific value) is taken into considertion in the calculation of the energy consumption.

---

1) In future, both products could possibly be manufactured from other raw materials as well:

   - the ethylene used to manufacture polyethylene could be obtained from biomass.
   - through the addition of flax fibres to inferior types of waste paper which are actually not suitable for use, they could be made suitable for the manufacture of paper carrier bags.

2) In principle, these residues could be used as raw materials for further products.

Finally, the availability of both types of raw material is limited. Consequently, they should be used, if possible, for durable goods and not for throw-away products.

No current data is available from the literature for the energy input for manufacturing cellulose and paper in the Federal Republic of Germany. Consequently, we had to work from the data basis for 1974. In order to take into account the significantly more efficient use of energy since then, the energy input was brought into line with current conditions analagous to the procedure of the Institute for Paper Manufacture /3/. On the other hand, the energy inputs calculated for paper manufacture given in the study by the Swiss Federal Office for Environmental Protection ("Ecological Balance of Packaging Materials" /7/) are regarded as being too high.

Kraft paper is imported from Scandinavia or Canada, or is manufactured in the Federal Republic of Germany from imported sulphate cellulose. As the respective portions are not known, only the (lower) expenditure of energy for the transportation from Sweden is used for the calculation of the expenditure of energy for the manufacture of paper carrier bags.

3.2. Damages to the Environment during Manufacture

The emissions of SO_2, NO_x, CO and dust are greater during the manufacture of paper carrier bags than they are during the manufacture of polyethylene carrier bags. On the other hand, the emissions of organic substances during the manufacture of polyethylene are higher than they are during the manufacture of paper. Altogether, the air-polluting emissions caused during the manufacture of paper carrier bags are to be regarded as clearly more damaging, compared with the manufacture of polyethylene carrier bags. In addition, there are emissions of sulphur compounds from the manufacture of paper, particularly during the manufacture of sulphate cellulose, which have an intense smell (hydrogen sulphide and mercaptans) and which cannot be included quantitatively in the comparison.

Also, the comparison of pollution of waste water turns out to be unfavourable as far as paper is concerned, because the CSB and BSB_5 values are many times higher than during the production of polyethylene carrier bags. This is valid for the use of unbleached kraft paper and, to a much greater extent, for the use of the paper combination included in the assessment. With this, there is additional pollution of the waste water from organic chlorine compounds, because it contains a portion of bleached cellulose. The chlorinated organic substances do not break-down easily and show a high degree of being poisonous to fish[1]. Furthermore, the possibility cannot be excluded that the effluents from bleaching could also contain dioxins in addition to chlorinated lignin and chlorinated phenols for example /9/. For this reason, the Swedish environmental authority is pressing for a quick reduction in the pollution of these waste waters /10, 11, 12/. In the Federal Republic of Germany at present a specific pollution of waste water of 1 kg/t cellulose is being discussed as the minimum demand, within the framework of revising the 19th Administrative Regulation of the Water Balance Law.

---

1) For example, soon in Sweden this pollution is to be reduced through a partial change from chlorine bleaching to oxygen bleaching /8/.

It is difficult to quantify the water pollution for the manufacture of carrier bags made from polyethylene through the extraction and transport by ship of the crude oil. The pollution of the waste water from hydrocarbons and phenols during the processing of the crude oil is relatively small.

3.3. Waste Management

The waste management of polyethylene and paper carrier bags is carried out with the domestic refuse on disposal sites and in incineration plants (see chapter 3.3 of the appendix).

Initially, paper carrier bags require a larger volume of space on the disposal site compared with polyethylene carrier bags. However, the period of decomposition is relatively short. On the other hand, polyethylene is subject to a very long-term microbial and chemical decomposition. In both cases, pollution to the waters seeping into the ground can occur, depending on the harmful substances released.

The situation regarding emissions from waste incineration plants operated at the current level of technology is not influenced differently by paper or polyethylene carrier bags.

The heavy metal content in the raw materials polyethylene and paper is to be classified as small in each case /3/. Pollution of the waters seeping into the ground at disposal sites and an influence on the emissions from waste incineration plants are possible through the use of colours containing heavy metals to colour and print on the carrier bags.

Altogether, there were no aspects of the waste management of polyethylene and paper carrier bags which lead to a fundamentally different evaluation.

3.4. Valorisation of Residues

As in comparable areas of industry, the valorisation of residues is normal practice.

On the other hand, in the area of domestic refuse, the practice of recycling is unsatisfactory. In some communities, the valorisation of certain plastic waste, including polyethylene, is being tried out within the framework of the campaign "Green Dustbin"; its economic and ecological usefulness is disputed.

Paper carrier bags can be valorised through collections of domestic paper, as "waste paper of a lower grade". The portion of waste paper in paper production at present comprises 43%; there is no sign of a further increase in the percentage.

So far, it is not possible to manufacture carrier bags from "waste paper of lower grades", because no paper with sufficient strength can be produced from it. However, it is being considered whether or not to manufacture a strong recycled paper from such waste paper mixed with flax fibres. A paper carrier bag could be made from this recycled paper which would be less of a burden to the environment and could be used for the municipal collection of kitchen waste with the aim of producing a high quality compost, low in harmful substances /13/.

Currently, in respect of the consideration of comparison, there is no significant difference between polyethylene and paper bags. This could be changed by a development towards flax-fibre paper.

3.5. Comparison with Shopping Bags

A repeated use of paper and, in particular, polyethylene carrier bags is possible; as a rule, however, their use as a shopping bag more than once will remain the exception.

In contrast with this, the traditional, sturdier shopping bag is used many times. Consequently, they are to be preferred to polyethylene and paper carrier bags from an ecological standpoint.

As an example, two differing shopping bags will be evaluated below from the same prerequisites as polyethylene and paper carrier bags. The assumptions and estimations decided upon were chosen rather to the benefit of the one-way carrier bag.

Polyamide Folding Bag

The following prerequisites were decided upon for the assessment: The folding bag made from polyamide fibres can be used (at least) 100 times and thus replaces 100 one-way carrier bags (made from polyethylene or paper). The weight is about 70g; accordingly, 500 polyamide folding bags corresponding to 50,000 one-way carrier bags, weigh 35 kg. Kindler and Nikles give the energy equivalent value for polyamide as 156 MJ/kg, /5/. An energy equivalent value of a maximum of 180 MJ/kg is estimated for everything involved in the processing from technical polyamide to the finished carrier bag. Consequently, 500 carrier bags have an energy requirement of 6.3 GJ and, thus, about only 10% of the energy expended to manufacture a comparable number of polyethylene carrier bags (and only 7% compared with paper carrier bags). As the energy input structure is comparable, the emissions are correspondingly lower.

Jute Bags

Carrier bags made from jute fibres (which became well-known under the slogan "jute instead of plastic") also require less than 10% of the energy expended in the manufacture of a comparable number of polyethylene carrier bags. It is assumed that they will be used at least fifty times and, therefore, they replace 50 one-way carrier bags. The energy requirement for jute carrier bags comprises 20 to 30 MJ/kg /14,15/. Thus, 1000 jute carrier bags with a weight of 120g each, corresponding to 50,000 one-way carrier bags, require approximately 5 GJ. The energy is put in for washing, weaving and sewing the jute fibres and bags, as well as for transport.

In addition to the significantly lower energy consumption and the correspondingly lower emissions, shopping bags also lead to only about 10% of the quantity of waste.

From an ecological point of view, shopping bags which can be used repeatedly are clearly preferable to a one-way carrier bag.

3.6. Conclusion

The comparison of carrier bags, such as those offered in retail grocery shops for example (12L volume and a load-bearing capacity of about 5 kg), comes to the conclusion:

For ecological reasons, it is not sensible to change from polyethylene to paper carrier bags. Polyethylene carrier bags require less energy for manufacture and cause, in all, less damage to the environment (chapter 3.1 and 3.2 of the appendix). There is no significant difference between the polyethylene and paper carrier bags regarding waste management on disposal sites or in waste incineration plants (chapter 3.3 of the appendix). This is where the (common) problem lies with the quantity of waste. However, even a change from paper to polyethylene carrier bags would not contribute significantly to a reduction of the burden on the environment. With the large number of one-way carrier bags used (annually almost 3 thousand millions in the Federal Republic of Germany), this is only possible by using reusable bags, e.g. made from polyamide or jute and, primarily, by using the traditional shopping bag. The energy consumption and the damage to the environment from the manufacture of that type of bag are many times less.

APPENDIX

TO THE COMPARISON OF THE EFFECTS ON

THE ENVIRONMENT FROM

POLYETHYLENE AND PAPER

CARRIER BAGS

CALCULATION OF THE ENVIRONMENTAL EFFECTS

CONTENTS

CONTENTS (Page 2)

1. MANUFACTURE OF POLYETHYLENE FILMS FOR CARRIER BAGS

Owing to its outstanding importance for the manufacture of carrier bags, the manufacture of LDPE (Low Density Polyethylene) is investigated.

1.1. Energy Consumption

Ethylene used to manufacture polyethylene can be manufactured from different raw materials. Whilst natural gas is used predominantly in the USA /7,16/, the bulk of the ethylene used in the Federal Republic of Germany comes from cracking naphtha, a product from petroleum /17/. The natural gas extracted in Europe is not suitable for the manufacture of ethylene.

The calculation of the energy consumption is based on energy equivalent values for plastics ascertained by Kindler and Nikles /4,5/. In the series of lectures by Pothmann "Future Demands on Manufacturers of Paper" /6/, this work is regarded as particularly reliable, especially in comparison with other energy balances of polyethylene. At the same time, the following marginal requirements are taken as a basis /5/:

- The energy equivalent value for the raw materials found in nature is determined on the basis of its incineration enthalpy (lower calorific value).
- The economically optimal processes already described on a large technological scale are taken as the basis for the manufacture of the products, although they do not necessarily have the lowest energy consumption[1].
- The evaluation of by-products which can be used further results essentially from the consideration of energetic points of view (energy equivalence values).
- All of the energy necessary (steam, electricity, fuels) and aids (cooling water, pressured gases, chemicals) are taken into account. The quantity of primary energy required for their preparation is calculated.
- An average degree of effectiveness of 38% /18/ is calculated for the manufacture of electricity, which the industry gets from the municipal concerns supplying energy (EVU). The loss of about 5% of the municipal electricity supply during transfer is taken into account.

  The result of this is an energy equivalence value of 10.2 MJ for 1 kWh of electricity.

---

1) As the data published by Kindler and Nikles is now almost 10 years old, it is assumed that the data no longer reflects the most economic data possible owing to further improvements in processes. However, it is assumed that the data represents the current situation of most plants and processes.

Kindler and Nikles /4/ give an energy equivalence value of 73 GJ/t for the manufacture of film from LDPE. This is comprised of the following individual energy consumption figures for each step of processing:

	Energy Equivalence Value/ (GJ/t)
Incineration enthalpy for petroleum (raw, lower calorific value) /18/	42.6
Transportation of petroleum (see 1.1.1.)	1.0
Obtaining naphtha (see 1.1.2.)	3.6
Production of ethylene (see 1.1.3.)	16.0
Polymerisation (see 1.1.4.)	6.1
Extrusion (see 1.1.5.)	3.7
	73.0

1.1.1 Transportation of Petroleum

The consumption of energy during the extraction of petroleum (own consumption) is not taken into account and, thus, is chargeable to the deposit reserves because the expenditure during the extraction of individual energy carriers (e.g. petroleum) can differ vastly /5/. (In the literature values of between 0.4% and 5% of the quantity of energy extracted are discussed for the energy consumption during the extraction of petroleum. The mineral oil industry gives values of between 0.5% and 1% for the North Sea and Saudi Arabia). Based on an energy equivalence value of 0.03 MJ/(t x km) for transportation with large tankers and a transportation distance of a maximum of 30,000 km, the transportation of petroleum results in a value of 1 GJ/t /5/, i.e. approximately 2% of the calorific value. Other sources list lower values (down to below 1%).

1.1.2 Obtaining Naphtha (Refinery)

The energy consumption and the losses during the refining are stated to be 4.5% by Kindler and Nikles and are added evenly to all distillation products /19/. On the other hand, the data in a TA-Air commentary by Davids and Lange /20/ reveals a consumption of 5.5% from the mineral oil industry's own consumption in respect of the petroleum throughput. Together with an addition for transportation, naphtha is taken into account in the calculation at 1.08 times its calorific value (at /5/ : 1.07). Consequently, with the calorific value of naphtha, an energy equivalence value of 47.2 GJ/t results. According to that, 3.6 GJ/t are necessary to obtain naphtha.

1.1.3 Production of Ethylene (Steam Cracking)

Depending on the conditions of cracking, ethylene, propylene, butadiene and other C_4 hydrocarbons, benzene pyrolysates (aromatics) and waste gases arise in differing proportions during the cracking of naphtha. On average, an ethylene portion of 30% is assumed. The total portion of products which are processed further as chemical raw materials, lies between 70% and 80%. The waste gas is used partially to produce energy.

The endothermic pyrolysis of naphtha to ethylene consumes relatively little energy. However, because of the necessarily high temperature (800°C to 900°C), the energy requirement for the cracking process is very high.

Kindler and Nikles give a nett energy requirement of 16 GJ/t /5/ for the production of ethylene, which results from the energy equivalence values of naphtha and ethylene. At the same time, all of the products used further in the chemical syntheses were taken into consideration. Using a study on the use of energy in the industry /21/ as a basis, one comes to the same result. Here an average, specific fuel consumption of 31 GJ/t is ascertained, whereby the total input of energy is put down to the production of ethylene alone. The requirement of electricity is given as 100 kWh/t ethylene. Taking into consideration the portion of ethylene (30%) in the products and the addition of a portion of waste gas, including the higher incineration enthalpy for ethylene, the energy equivalence value for the production of ethylene results in 16 GJ/t as well.

Hauss /22/ arrives at a lower energy equivalence value: 124m^3 methane and 22 kWh electricity are estimated per tonne naphtha throughput. At the same time, however, it is not clear whether the energy required to separate the mixed product and the energy input for burning the waste gases were added on. Consequently, these values were not taken into consideration any further.

1.1.4 Polymerisation

LDPE is manufactured through the polymerisation of ethylene under high pressure (over 1500 bar) and at increased temperatures in the presence of initiators which form radically. The process of polymerisation consumes electric energy essentially to produce pressure. According to Hauss /22/ 780 kWh/t LDPE are used. In the plant mentioned by Hauss, 80% of the electricity comes from municipal concerns supplying energy and 20% is obtained from their own thermal power plant. In some other production plants, the proportion of their own energy could also be higher.

The polymerisation of ethylene proceeds exothermically. A quantity of heat of about 3.5 GJ/t LDPE becomes free /9/; from this 600 kg/t LDPE in the form of medium pressure steam is given over to other consumers /22/. In another source /21/ a requirement of on average 850 kWh/t LDPE is given. However, it gives no details of the amount of electricity drawn or the use of the heat from polymerisation.

Because the extent of the power/heat coupling during the production of one's own electricity for LDPE production is not known, the calculation is made with the energy equivalence value of 10.2 MJ/kWh for the total amount of electricity drawn from the municipal concerns for supplying energy. Consequently, the energy consumption of 780 kWh for one tonne LDPE corresponds to 8.0 GJ/t LDPE; minus 1.9 GJ/t LDPE for the 600 kg medium pressure steam given off results in an energy equivalence value of 6.1 GJ/t LDPE for the polymerisation.

Kindler & Nikles /5/ give an energy equivalence value of the same quantity, i.e. 6 GJ/t, for this process. Even with a basis of 850 kWh/t LDPE in accordance with /21/ and under consideration of a relatively low proportion of own electricity of almost 20% with power/heat coupling /5/, an energy equivalence value of the same quantity is calculated for the polymerisation.

LDPE produced according to the high pressure process occurs in a molten form and is granulated directly ready for processing.

1.1.5 Film Extrusion and Transportation

The transportation of the LDPE granules to the processor requires 0.3 GJ/t LDPE of energy for an average transportation distance of 300 km /4,5/.

Kindler and Nikles give an electrical energy requirement of 300 to 450 kWh/t for the extrusion of films and pipes from plastic granules, which corresponds to a total expenditure of thermal energy of 3.0 to 4.6 GJ/t. The manufacture of LDPE films requires a processing expenditure of 3.4 GJ/t /4/. In contrast with this, Hauss /22/ gives an electrical energy consumption of only 250 kWh/t product for the manufacture of LDPE carrier bags (even printed). This corresponds to a thermal energy expenditure of 2.6 GJ/t. The higher value is included in the total energy balance for LDPE films (see 1.1). Thus, the energy equivalence value for extrusion and the transportation of granules is 3.7 GJ/t. As a rule, the processing of the LDPE film into finished carrier bags takes place in the same factory, so that no further transportation is necessary.

The distribution of the finished carrier bags is not taken into consideration, because the energy required for this is of a similar scale to that necessary for polyethylene and paper carrier bags.

1.2. Environmental Damage

When estimating the emissions, all of the significant processes relevant to emissions are investigated. At the same time, all of the energy equivalence values of products included in the energy balance, as well as the individual processing steps, are taken into consideration. Emissions from the manufacture of additives, processing aids, etc., are ignored because they comprise a low proportion of the total emissions. The emissions calculated relate to the manufacture of 1t of polyethylene film (LDPE).

1.2.1 Transportation of Petroleum

The amount of petroleum necessary for the manufacture of one tonne LDPE, which therefore has to be transported, is calculated as follows[1]:

---

1) The emissions from the transportation of materials to the production of energy are not taken into consideration.

1.038 t ethylene is required for the polymerisation to 1 t LDPE /23/. During the cracking of naphtha, in addition to the petrochemical products which can be valorised, waste gases and waste oils occur, which are used to produce energy and whose lower calorific values are added to the energy balance. The emissions from the processes are added only to the petro-chemical products which can be valorised. Over and above this, hydrocarbons are emitted through the process. Consequently, in order to manufacture 1.038t enthylene, a total of 1.3t naphtha must be cracked. In order to manufacture this quantity of naphtha, an equivalent quantity (factor 1.08, see 1.1.2) of 1.4t petroleum must be transported and processed in refineries.

The energy equivalence value for the transportation of petroleum in large tankers is 1GJ/t /5/. At a lower calorific value of approximately 41GJ/t (calorific value for fuel oil /18/) for the ship's diesel oil, the transportation of 1.4t petroleum (for the manufacture of 1t LDPE) requires 34 kg of ship's diesel oil.

The residues from the distillation of petroleum are used predominantly as diesel oils for ships. The engines of tankers are suited to burning these highly-viscous, heavy oils. The emission factors related to this are derived essentially from the land register of emissions for the City of Hamburg /24/. On average, the content of sulphur is set at 3% /25/.

Table 1

Emissions from the transportation by ship of petroleum for 1 t LDPE:

Quantity of input Diesel Oil	x	Emission Factor	=	Emission per t LDPE
34 kg	x	60 g SO_2/kg	=	2.04 kg SO_2
34 kg	x	41 g NO_x/kg	=	1.39 kg NO_x
34 kg	x	6 g CH/kg	=	0.20 kg CH
34 kg	x	18 g CO/kg	=	0.61 kg CO
34 kg	x	2.5 g Dust/kg	=	0.09 kg Dust

Ruzicka and colleagues investigated the combustion characteristics of such heavy oils in a test engine and provided emission factors /26/. This engine is not comparable to a ship's diesel engine, because the number of revolutions is higher by about a factor of 2 to 10. In particular, the emissions of dust from the test engine running with normal diesel oil in the factory were already almost ten times higher than they would be, as a rule, for the combustion of diesel oil in normal units whilst motoring. The aim of Ruzicka's work was the comparison of combustion properties for various heavy oils in a laboratory machine. For the reasons given, the emissions provided do not give the actual emissions which occur from a ship's engine powered by heavy oil. Consequently, they are not a suitable basis for ascertaining the emissions which occur from transportation by tanker.

An inclusive emission factor of 0.5 kg CH per tonne LDPE-films is taken into account for the various possible procedures of transfer (tanker, petrol depot, storage of naphtha, etc.).

Owing to a lack of a foundation for an assessment, sea pollution from the extraction and transportation of petroleum cannot be taken into consideration quantitatively.

1.2.2 Manufacture of naphtha (Refinery)

In order to manufacture 1t LDPE-film, an equivalent quantity of 1.4t petroleum (see 1.2.1) must be processed in the refinery. During this process, the following emissions occur /27/:

Table 2:

Emissions during the manufacture of naphtha from petroleum for 1t LDPE.

Quantity of input Petroleum	x	Emission Factor	=	Emission per t LDPE
1.4 t	x	1.6 kg SO_2/t	=	2.24 kg SO_2
1.4 t	x	0.36 kg NO_x/t	=	0.05 kg NO_x
1.4 t	x	0.4 kg CH/t	=	0.56 kg CH
1.4 t	x	0.04 kg CO/t	=	0.06 kg CO
1.4 t	x	0.06 kg Dust/t	=	0.08 kg Dust

The pollution of the waste water by refineries is limited by the 45th Waste Water Administrative Regulation (The processing of petroleum) /28/. At the same time, the following minimum requirements are valid for effluents being introduced after treatment in a purification plant (24-hour mixed sample):

CSB:	100 mg/L
BSB_5:	25 mg/L
Hydrocarbons:	5 mg/L
Phenol index after distillation (steam volatile phenols):	0.2 mg/L

For a 2-hour mixed sample, the requirements are 20% weaker. The following calculations are made using the highest loadings permitted.

The specific quantities of waste water in refineries in operation today amount to 0.2 to 0.5 m^3/t crude oil /29/. Using the higher value as a basis for the processing of 1.4 t crude oil/t LDPE, the following emissions result:

Table 3:

Pollution of waste water during the manufacture of naphtha for 1 t LDPE.

Quality of Crude Oil	x	Specific quantity of Waste Water	x	Highest loading permitted (Minimum Requirement)	=	Pollution of Waste Water per t LDPE
CSB:		1.4 t x 0.5 m^3/t	x	100 mg/l	=	70 g
BSB_5		1.4 t x 0.5 m^3/t	x	25 mg/l	=	17.5 g
CH:		1.4 t x 0.5 m^3/t	x	5 mg/l	=	3.5 g
Phenols:		1.4 t x 0.5 m^3/t	x	0.2 mg/l	=	0.14 g

The specific quantity of waste water for older refineries amounted to 1 to 3 m^3/t crude oil. As a large number of predominantly older refineries in the Federal Republic of Germany have shut down in the past few years, the quantities of waste water are lower today.

1.2.3 Manufacture of Ethylene (Steam Cracking)

About 97% of the equivalent quantity of energy of 16 GJ/t necessary to manufacture ethylene is produced from burning natural gas /20/, which is mixed with portions of waste gases from cracking naphtha /22/. The emissions are illustrated in Table 4.

Table 4:

Emissions from burning natural gas to manufacture ethylene for 1 t LDPE /30/.

Quantity of input Natural Gas	x	Emission Factor	=	Emission per t LDPE
15.5 GJ	x	1 g SO_2/GJ	=	0.016 kg SO_2
15.5 GJ	x	130 g NO_x/GJ	=	2.02 kg NO_x
15.5 GJ	x	5 g CH/GJ	=	0.078 kg CH
15.5 GJ	x	10 g CO/GJ	=	0.16 kg CO
15.5 GJ	x	0.1 g Dust/GJ	=	0.0016 kg Dust

About 3% (0.5 GJ/t) of the necessary quantity of energy is used to produce electricity, the greater part of which is drawn from the municipal concerns supplying energy.

Even examined carefully and relatively lavishly, it is often not adequately possible to include the electricity consumption of individual industries from particular types of power stations and fuels, considering the course of time of the power requirements and the way in which the power station is used. Consequently, Kindler &

Nikles approach /5/ is adopted here, the basis of which is the production of electricity from fossil fuels, particularly as this approach does not lead in anyway to an unfavourable result for paper.

Consequently, the emission factors used give the emissions from municipal power stations which are to be added on to the production of electricity from fossil fuels corresponding to their quantity of input. See Table 5.

Table 5:

Emissions during the production of electricity from fossil fuels in municipal power stations to manufacture ethylene for 1 t LDPE /30/.

Quantity of input Primary energy	x	Emission Factor	=	Emission per t LDPE
0.5 GJ	x	605 g SO_2/GJ	=	0.303 kg SO_2
0.5 GJ	x	293 g NO_x/GJ	=	0.147 kg NO_x
0.5 GJ	x	3 g CH/GJ	=	0.002 kg CH
0.5 GJ	x	13 g CO/GJ	=	0.007 kg CO
0.5 GJ	x	34 g Dust/GJ	=	0.017 kg Dust

In addition, during the cracking of naphtha, emissions of hydrocarbons occur from diverse sources (fittings, seals), which are given by Hauss to be 1.74 kg/t mixed product of ethylene and propylene /31/. It seems justified to put the loads for the emissions of hydrocarbons down to the production of ethylene and propylene alone, because the emissions consist predominantly of gaseous products, the main proportions of which are ethylene and propylene.

The pollution of waste water from the cracking of naphtha is limited by the 36th Waste Water Administrative Regulation (Manufacture of Hydrocarbons) /32/. The minimum requirement valid for steam cracking is a load value (24-hour mixed sample) of 1 kg/t ethylene for the chemical oxygen demand. 1.3t naphtha must be cracked to manufacture 1 t LDPE (see 1.2.1). The percentage of ethylene in the product mixture, including a portion of petro-chemical residues which cannot be exploited, amounts to almost 40%. From this, a CSB of 0.5 kg/t results related to the production of LDPE.

1.2.4 Polymerisation

A quantity of primary energy of 6.1 GJ/t LDPE is necessary for the electricity required for the polymerisation of ethylene to LDPE (see 1.1.4). See Table 6.

Table 6:

Emissions during the production of electricity from fossil fuels in municipal power stations for the polymerisation of 1t LDPE /30/.

Quantity of input Primary Energy	x	Emission Factor	=	Emission per t LDPE
6.1 GJ	x	605 g SO_2/GJ	=	3.69 kg SO_2
6.1 GJ	x	293 g NO_x/GJ	=	1.79 kg NO_x
6.1 GJ	x	3 g CH/GJ	=	0.018 kg CH
6.1 GJ	x	13 g CO/GJ	=	0.079 kg CO
6.1 GJ	x	34 g Dust/GJ	=	0.21 kg Dust

Furthermore, during high-pressure polymerisation, diverse emissions from ethylene occur of 1.1 kg CH/t LDPE /31/.

1.2.5 Film Extrusion and Transportation

0.3 GJ/t are necessary for the transportation of LDPE-granules to the processor. This is equivalent to 7 kg diesel fuel/t LDPE for transportation by lorry. See Table 7 for the emissions.

Table 7:

Emissions during the transportation by lorry of 1 t LDPE-granules /33/.

Quantity of input Diesel	x	Emission Factor	=	Emission per t LDPE
7 kg	x	4.0 g SO_2/kg	=	0.028 kg SO_2
7 kg	x	58.3 g NO_x/kg	=	0.408 kg NO_x
7 kg	x	12.0 g CH/kg	=	0.084 kg CH
7 kg	x	15.0 g CO/kg	=	0.105 kg CO
7 kg	x	4.3 g Dust/kg	=	0.030 kg Dust

The consumption of electricity during film extrusion necessitates a primary energy expenditure of 3.4 GJ/t to produce electricity. See Table 8 for the emissions.

Table 8:

Emissions during the production of electricity from fossil fuels in municipal power stations for the extrusion of 1 t LDPE-film /30/.

Quantity of input Primary Energy	x	Emission Factor	=	Emission per t LDPE
3.4 GJ	x	605 g SO_2/GJ	=	2.06 kg SO_2
3.4 GJ	x	293 g NO_x/GJ	=	1.00 kg NO_x
3.4 GJ	x	3 g CH/GJ	=	0.010 kg CH
3.4 GJ	x	13 g CO/GJ	=	0.044 kg CO
3.4 GJ	x	34 g Dust/GJ	=	0.116 kg Dust

1.2.6 Total Damage

The total damages to air and water during the manufacture of polyethylene films (Chapters 1.2.1 to 1.2.5) are summarised in Table 9.

Table 9:

Total damage to air and water during the manufacture of 1 t polyethylene film.

Air-Polluting Emissions:	SO_2	10.38 kg
	NO_x	7.26 kg
	CH	4.29 kg
	CO	1.06 kg
	Dust	0.54 kg
Loadings in Waste Water	CSB	570 g
	BSB_5	17.5 g
	CH	3.5 g
	Phenols	0.14 g

2. MANUFACTURE OF PAPER FOR CARRIER BAGS

Paper carrier bags are manufactured predominantly from so-called kraft paper made from primary fibrous material /34/:

"Although it is not impossible for this type of paper to be produced by adding more or less large quantities of very high-quality, wood-free waste paper with a high strength - desired value, it can be assumed for the greater part of this product that primary fibres in the form of bleached and unbleached conifer sulphate cellulose will be used exclusively. This special type of cellulose is not produced in the Federal Republic of Germany. Thus, it has to be assumed for the majority that German processors import the raw paper from Canada or Scandinavia."

However, certain products and/or parts of products can be manufactured from sulphite cellulose which, mind you, has a lower strength owing to its shorter fibres compared with sulphate cellulose. In the Federal Republic of Germany, sulphite cellulose is manufactured exclusively.

The manufacture of sulphate and sulphite cellulose takes place with differing chemical breaking down processes, through which the cellulose is separated from the lignin in wood. Detailed descriptions of this are given in the literature /35,36/.

The data for the energy consumption during the manufacture of paper are based on the results of a study by the Institute for Paper Manufacture in Darmstadt /3/, which has evaluated the current literature available. In order to reproduce a summary which gives the gist of these results (basis and prerequisites for the calculations), the relevant chapter and the places in the literature which refer to it are quoted fully. On the other hand, a similar study "Tetra Brik Environmental Profile" /37/ refers to data from individual companies and, consequently, is used in only a limited way within the framework of this comparison.

The study made in Darmstadt is subject in principle to the difficulties of ascertaining damage to the environment in this area:

The differing technological standards of the same processes of production in the cellulose and paper industry lead to a greater range in energy consumption and emissions and makes it more difficult to establish general data.

Differing technological processes for the manufacture of paper, such as the manufacture of cellulose (including drying) in Canada and Scandinavia, followed by the manufacture of paper in the Federal Republic of Germany on the one hand, or the integrated manufacture of cellulose and paper (without drying the cellulose) in the countries producing cellulose on the other hand, cause differing consumptions of energy, for example. Thus, a steam requirement of 1.5 t steam/t cellulose is estimated for drying the cellulose. Based on an energy equivalent value for steam of 3.12 GJ/t /5/, this corresponds to a primary energy requirement of 4.7 GJ/t cellulose, which is not necessary for the integrated manufacture of cellulose and paper.

To some extent, it is not clear from the study why certain processes and emission factors were used as a basis. Consequently, in some cases the details of this study are supplemented by data ascertained elsewhere.

The energy consumption and the emissions from the manufacture of unbleached and bleached sulphate cellulose and of bleached sulphite cellulose are described below.

2.1. Energy Consumption

2.1.1 Manufacture of Cellulose:

As a rule, cellulose is manufactured in densely wooded areas, so that the wood required does not have to be transported over large distances. 100 km is fixed as an average distance of transportation. The transportation of the wood occurs primarily by lorry with an energy equivalent value of 1.0 MJ/(t x km) /5/. 2 t of wood is necessary to manufacture 1 t cellulose /3/. Consequently, the energy consumption for the transportation of the wood results in 0.2 GJ/t paper.

2.1.1.1 Sulphate Cellulose

The Institute for Paper Manufacture says the following about the manufacture of cellulose /3/[1]:

"Energy in the form of electricity or steam is necessary to manufacture cellulose. The total energy requirement to manufacture bleached sulphate cellulose is in the area of 20.5 to 38.5 GJ/t /38-41/. If one deducts the energy requirement of 1.3 to 6.6 GJ/t /41/ for the operation of the bleaching plant, then an energy consumption for the manufacture of unbleached cellulose of 19.2 to 31.9 GJ/t is the result. The average value for 24 kraft cellulose factories investigated in Canada and Scandinavia /41/ is 24.4 GJ/t for unbleached and 27.9 GJ/t for bleached sulphate cellulose. On average 54.5% of this energy requirement is gained from burning the waste lye, barks and waste materials, so that the energy requirement to be covered by fossil fuels amounts to 11.1 GJ/t for unbleached and 12.7 GJ/t for bleached cellulose. However, the emissions of harmful materials given later relate to the use of both sources of energy. Analogous to the calculation for polyethylene, for the energetic total assessment the energy consumption for wood of 16 GJ/t /42/ must be added on to that for fossil fuels, to the factor 2 because of the approximately 50% gain during the breaking down process. From this, a total theoretical energy consumption results of:

Sulphate cellulose unbleached: 11.1 GJ/t + (2 x 16GJ/t)=43.1 GJ/t
Sulphate cellulose bleached: 12.7 GJ/t + (2 x 16GJ/t)=44.7 GJ/t

It is not permissible to add the total energy requirement for the manufacture of cellulose (24.4 or 27.9 GJ/t) to twice the calorific value of wood (2 x 16 GJ/t), because a credit of energy results from burning the leach and barks."

---

1) The numbering of the literature sources in the quotation is always adapted to correspond in the following and is marked in the bibliography with "quoted according to /3/".

Even lower energy consumptions are possible at individual plants /8/. However, as these cannot be regarded as representative, they are not taken into consideration here.

2.1.1.2 Sulphite Cellulose (Federal Republic of Germany)

In the Federal Republic of Germany, wood is broken down by the sulphite process. According to /3/, the following consumption of energy is calculated for this:

"It is to be assumed that, during the production of bleached sulphite cellulose, the electrical energy requirement is 3.3 GJ/t[1] and the steam requirement is 25.9 GJ/t (total: 29.2 GJ/t). The burning of leach, barks and waste covers an energy portion of 48% /43/. This leaves 15.2 GJ/t energy requirement to be met by fossil fuels. The addition of the calorific value of wood of 16 GJ/t, calculated with a 50% gain in the same way, gives a total theoretical energy consumption of:

15.2 GJ/t + (2 x 16 GJ/t) = 47.2 GJ/t
bleached sulphite cellulose

It should be noted that, without exception, the specific energy consumptions for the manufacture of sulphite cellulose and paper are based on older data material. However, owing to its totality and detailed classification, it is to be assessed as being representative. It is to be assumed that the current energy requirement is lower, owing to energy saving measures. In 1977 (based on the requirement in 1974), the possible energy saving in the whole of the paper and cellulose industry up to the year 1985 was estimated at 17.3% /44/. From the reports of achievements of the Association of German Paper Factories, it is clear that the specific energy consumption (calculated as the fuel input plus the foreign electricity drawn) in the Federal Republic of Germany fell from 0.55t SKE/t cellulose and paper in 1974 to 0.45t KE/t cellulose and paper in 1984. This is the equivalent of a real percentage saving of 18.2%. Consequently, the following calculations assume a reduced energy requirement of 18% for the manufacture of sulphite cellulose and paper."

The following data results from this for the manufacture of sulphite cellulose (Situation 1984) per t cellulose:

Energy requirement from fossilised fuels: 15.2 GJ/t - (15.2 GJ/t x 0.18)	=	12.4 GJ/t
Addition of calorific value of wood: 2 x 16 GJ/t	=	32.0 GJ/t
Theoretical energy consumption (incl. calorific value of wood at 50% gain)	=	44.4 GJ/t

14 GJ/t are used through internal recycling of energy in the company.

---

1) In the plant described in /43/, the electricity is produced in a counterpressure plant. At the same time, the electricity is calculated in the same way as the heat, without taking into consideration the degree of efficiency of the fuel.

2.1.2 Manufacture and Transportation of Paper

The following energy requirement is necessary during the manufacture of paper /3/:

"A constant energy requirement can be assumed for the manufacture of paper from cellulose, independent of the input of raw materials (sulphite cellulose, sulphate cellulose). In 1973, the average value for the energy requirement (steam and electrical energy)[1] for the whole of the manufacture of kraft paper amounted to 9.9 GJ/t and included the preparation of materials, dehydration and drying /44/. This was based on an input of raw materials of 50% waste paper and 50% cellulose. The material preparation of cellulose - particularly the grinding - needs an energy requirement about 50 kWh/t higher than that needed for waste paper. For our example, which is based on 100% cellulose, this amount (= 0.2 GJ/t) must be added on to the total energy requirement, so that this amounts to 10.1 GJ/t.

Owing to the lower energy for grinding, the manufacture of paper containing waste paper needs, in total, a lower energy requirement of 7.4 to 8.2 GJ/t /44/. In the following, the average value of 7.8 GJ/t is used as a basis.

Both data must be reduced by 18% for the reasons given in chapter 3.1.2.2[2]. Following calculations will be made with an energy requirement of 8.3 GJ/5 kraft paper and 6.4 GJ/t paper containing waste paper."

For the manufacture of paper from cellulose 0.2 GJ.t must be added on to the values calculated by the Institute for Paper Manufacture, because the expenditure of electricity of 50 kWh/t taking into consideration a portion of power/heat coupling, necessitates a primary energy input of 0.4 GJ/t (/3/ : 0.2 GJ/t).

On the other hand, the Foundation of Paper Technology /34/ gives an electrical energy requirement of 900 to 1000 kWh/t and a thermal energy requirement of 1300 to 1600 kWh/t product for the manufacture of raw paper, including the preparation of the cellulose.

On the basis of about one-third power/heat coupling /34/ and a degree of efficiency of 49%[3] for the production of electricity in Sweden, in total an average primary energy requirement of 12 GJ/t results for the energy inputs given. In the following calculations are made using the lower value from the Institute of Paper Manufacture.

---

1) The degree of efficiency for the production of electrical energy was not taken into consideration by the Institute for Paper Manufacture. However, according to the importance of the individual contributions of energy, the total energy requirement seems plausible. It is calculated as 9.9 GJ/t.
2) In this report it is chapter 2.1.1.2.
3) The degree of efficiency was ascertained with a portion of electricity from water-power, taking into consideration the actual degree of efficiency of water power.

The transportation of kraft paper made from sulphate cellulose is predominantly by train. At the same time, an average transportation distance of 1500 km (Sweden - Federal Republic of Germany) is fixed. With an energy equivalence value of 0.4 MJ/ (t x km) /5/, this gives a primary energy consumption of 0.6 GJ/t.

For the transportation by lorry of paper made from sulphite cellulose at an average transportation distance of 300 km, analogous to the transportation of LDPE-granules (see 1.1.4), energy of 0.3 GJ/t paper is required.

2.1.3. Total Energy Consumption

The energy equivalence value for the manufacture of 1 t of paper can be worked out by adding together the individual energy consumptions (Table 10).

Table 10:

Total energy consumption for the manufacture of paper.

	Kraft Paper		Sulphite Paper
	Unbleached	Bleached	Bleached
Transportation of wood	0.2 GJ/t	0.2 GJ/t	0.2 GJ/t
Manufacture of cellulose	43.1 GJ/t	44.7 GJ/t	44.4 GJ/t
Manufacture of paper	8.5 GJ/t	8.5 GJ/t	8.5 GJ/t
Transportation of paper	0.6 GJ/t	0.6 GJ/t	0.3 GJ/t
Energy equivalence value (total)	52.4 GJ/t	54.0 GJ/t	53.4 GJ/t

The preparation of the waste paper, including the transportation of the paper requires energy of 6.7 GJ/t paper /3/.

2.2. Environmental Damage

The calculation relates to the manufacture of 1 t paper. As in the manufacture of polyethylene, emissions from additives, aids, etc., during manufacture are not taken into account.

2.2.1 Manufacture of Cellulose

The transportation by lorry of the wood to the cellulose factory requires 0.2 GJ/t paper. This is equivalent to a consumption of 4.7 kg of diesel fuel. See Table 11 for the emissions.

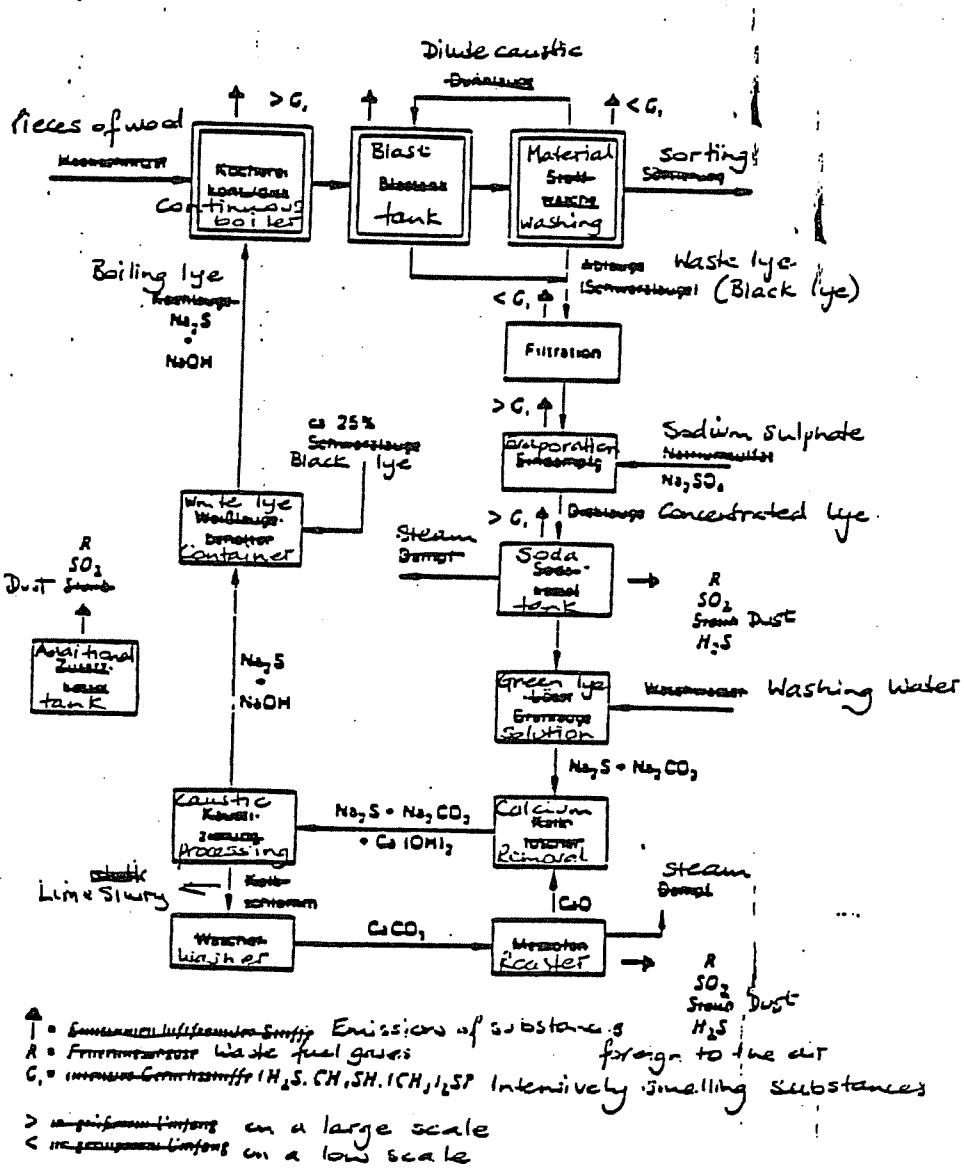
Table 11:
Emissions during the transportation by lorry of wood for the production of 1 t paper /33/.

Quantity of input Diesel	x	Emission Factor	=	Emission per t Paper
4.7 kg	x	4.0 g SO_2/kg	=	0.019 kg SO_2
4.7 kg	x	58.3 g NO_x/kg	=	0.274 kg NO_x
4.7 kg	x	12.0 g CH/kg	=	0.056 kg CH
4.7 kg	x	15.0 g CO/kg	=	0.071 kg CO
4.7 kg	x	4.3 g Dust/kg	=	0.020 kg Dust

2.2.1.1 Sulphate Cellulose

In diagram 1, the steps necessary to manufacture sulphate cellulose and the sources of emissions are represented in a diagram of the course of events.

Diagram 1:
Processing course and sources of emissions in breaking down sulphate /45/.



From the literature listed, The Institute for Paper Manufacture has given the following specific emissions into the air and says about it furthermore /3/:

"Waste air

SO_2,	kg/t	/38,39,46,47/:	0.1 - <u>5.3</u> - 74
NO_x,	kg/t	/38/:	0.4 - <u>0.8</u> - 1.5
CO,	kg/t:		no details
CH,	kg/t	/48/:	0.2 - <u>0.6</u> - 1.0
Dust,	kg/t	/39,46/:	1.0 - <u>1.5</u> - 2.0

The values listed are the minimum and maximum emissions, reproduced from the literature. The value underlined represents the total average value calculated from the average values of each individual passage in the literature and, thus, is probably the most meaningful value overall.

Owing to a lack of detail in the literature, it is not possible to differentiate between the emissions for bleached and unbleached sulphate celulose. The data listed above refer to bleached cellulose and are also used as a basis for unbleached.

No details could be found in the literature for specific emissions of carbon monoxide. However, a zero emission is improbable. Passage 48 in the literature has an illustration, from which it is clear that there is a relatively good connection between the emission of hydrocarbon compounds from sulphate cellulose factories and the emission of carbon monoxide. Nonetheless, this is not a linear correlation. According to the passages in the literature given above, in the area of CH-damage to be taken into consideration, the conversion factor for CO is about 2.5. Consequently, the average CO-emission is estimated to be 1.5 kg/t and is taken into consideration in further calculations."

The NO_x-emissions value given in the study is clearly too low. The Swedish environmental protection authorities are striving for an emission value for NO_x of 0.1 kg/GJ /49/; this alone is equivalent to a specific emission of 2.8 kg/t paper for bleached cellulose (the current emissions are probably higher) at a total energy consumption (fossil fuels and the incineration of the waste lye) of 27.9 GJ/t (see 2.1.1.1). By the way, the average values ascertained by the Institute for Paper Manufacture are used in further calculations, see Table 12.

Table 12:
Emissions during the manufacture of sulphate cellulose for 1 t paper.

Emission per t paper
5.3 kg SO_2
2.8 kg NO_x
0.6 kg CH
1.5 kg CO
1.5 kg Dust

Over and above this, during the manufacture of sulphate cellulose emissions of intensively smelling sulphur compounds, such as hydrogen sulphide, mercaptans and organic sulphides occur, which can be reduced by bringing them into the incineration process. According to Sundström /37/, the remaining emissions of hydrogen sulphide in a Swedish factory are 0.194 kg/t paper (cardboard). The emissions of organic sulphide compounds are lower in general. The Institute for Paper Manufacture says about waste water pollution /3/:

"The following values represent the range of specific emissions during the manufacture of sulphate cellulose. As, to some extent, we have to fall back on literature in English, the BSB_7 is equivalent to the BSB_5.

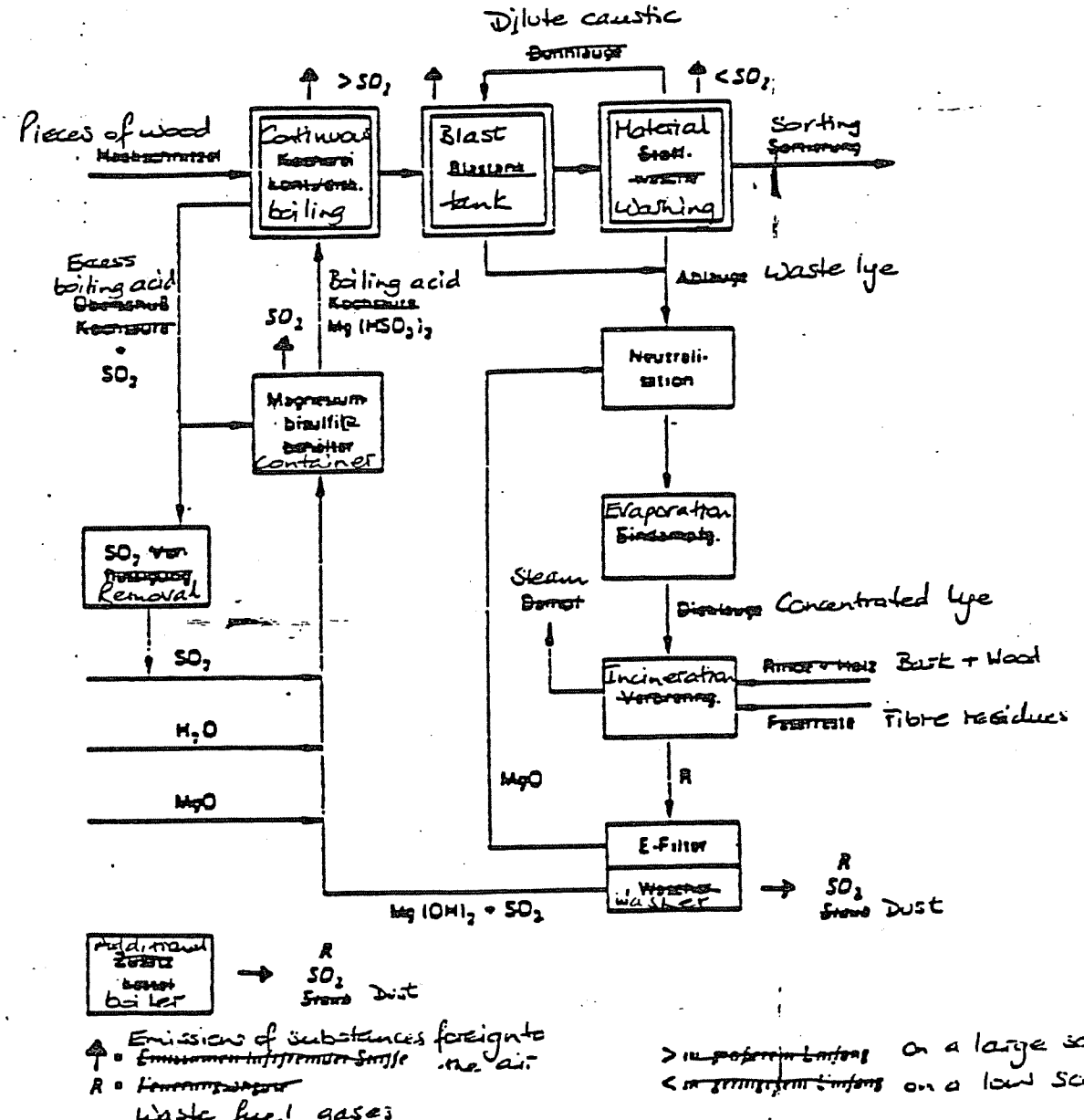
Waste Water	Unbleached	Bleached
CSB, kg/t /39, 50,. 51, 52/:	0.5 - 2.5 - 6	40 - 61 - 80
BSB_5, kg/t /39, 53, 51, 54, 52/:	0.1 - 0.7 - 2	7 - 21 - 31"

Furthermore, the stretches of water are damaged by suspended solid substances. With bleached celluloses, the organic chlorine compounds (chlorinated lignin, chlorinated phenols, etc) are particularly relevant to the environment. In Sweden, the specific emissions of these chlorine compounds are estimated to be 3.5 kg/t cellulose /10,11/.

2.2.1.2 Sulphite Cellulose (Federal Republic of Germany)

Diagram 2 shows the sequence of events during the manufacture of sulphite cellulose using the example of magnesium bisulphite processing.

Diagram 2 : Course of process and sources of emissions during magnesium bisulphite processing /45/.



The energy necessary to manufacture sulphite cellulose is met predominantly by the incineration of the waste lye and fossilized carriers of energy in the factories' own power station. The primary energy input is 12.4 GJ/t.

According to /55/[1] the following percentage division of primary energy carriers results for the energy produced in the factories' own power stations:

37% Fuel Oil
36% Gas
23% Hard coal
4% Brown coal

The emissions which can be traced back to this are given in Table 13, where the fuel-specific emission factors for municipal power stations are also given for the energy produced in the factories' own power stations, as these are more favourble as a rule.

Table 13

Emissions during the incineration of primary carriers of energy (see the text for composition) in factories' own power stations for 1 t paper (according to /30/).

Quantity of input Primary energy	x	Emission Factor	=	Emission per t Paper
12.4 GJ	x	463 g SO_2/GJ	=	5.74 kg SO_2
12.4 GJ	x	204 g NO_x/GJ	=	2.53 kg NO_x
12.4 GJ	x	3.6 g CH/GJ	=	0.045 kg CH
12.4 GJ	x	5.8 g CO/GJ	=	0.072 kg CO
12.4 GJ	x	17.3 g Dust	=	0.215 kg Dust

Taking the production of cellulose in the Federal Republic of Germany and the total energy from incineration of the waste lye as a basis /55/, the result is a specific energy input of 14 GJ/t. The emissions in Table 14 result from the emission factors of incineration of the sulphite waste lye /56/.

1) The figures given here relate to the whole of the cellulose and paper industry in the Federal Republic of Germany.

Table 14:

Emissions from incineration of the sulphite waste lye for 1 t paper /56/.

Quantity of input	x	Emission Factor	=	Emission per t Paper
14 GJ	x	1.92 kg SO_2/GJ	=	26.9 kg SO_2
14 GJ	x	0.16 kg NO_x/GJ[1]	=	2.24 kg NO_x
14 GJ	x	0.1 kg CH/GJ[1]	=	1.4 kg CH
14 GJ	x	1.0 kg CO/GJ[1]	=	14.0 kg CO
14 GJ	x	0.24 kg Dust/GJ[1]	=	3.36 kg Dust

Furthermore, sulphur dioxide emissions occur during several of the processing steps for manufacturing cellulose. They amount to 5 kg SO_2/t paper /57/.

The Institute for Paper Manufacture gives the waste water pollution as follows /3/:

"During the manufacture of bleached sulphite cellulose the followimg emissions occur:

Waste Water

CSB, kg/t /58, 51, 59, 60, 61/: 38 - 107 - 220
BSB_5, kg/t /53, 58, 51, 61/: 5 - 45 - 84"

In the Federal Republic of Germany, the proportion of chlorinated organic compounds (AOX) is estimated to be 4-5 kg/t cellulose /62/.

2.2.2 Manufacture and Transportation of Paper

The manufacture of paper necessitates a primary energy input of 8.5 GJ/t (see 2.1.2).

This energy is not only drawn from the municipal network in the form of electricity (55%), but also produced in the factories' own power stations (the percentage distribution corresponds to that in 2.2.1.2).

---

1) These emission factors do not come from measurements taken during the incineration of the waste lye, but correspond to emission factors for industrial wood firing, which have been assumed analogously here.

Primary energy carriers corresponding to 4.7 GJ/t are put in for the production of electricity in municipal power stations (see Table 15 for the emissions), and 3.8 GJ/t for that produced in the factories' own power stations (see Table 16 for emissions).

Table 15:

Emissions during the production of electricity from fossil fuels in municipal power stations to manufacture 1 t paper /30/.

Quantity of input Primary Energy	x	Emission Factor	=	Emission per t Paper
4.7 GJ	x	605 g SO_2/GJ	=	2.84 kg SO_2
4.7 GJ	x	293 g NO_x/GJ	=	1.38 kg NO_x
4.7 GJ	x	3 g CH/GJ	=	0.014 kg CH
4.7 GJ	x	13 g CO/GJ	=	0.061 kg CO
4.7 GJ	x	34 g Dust/GJ	=	0.160 kg Dust

Table 16:

Emissions from the incineration of the composition of primary energy carriers mentioned in 2.2.1.2 in factories' own power stations to manufacture 1 t paper (according to /30/).

Quantity of input Primary Energy Carrier	x	Emission Factor	=	Emission per t Paper
3.8 GJ	x	463 g SO_2/GJ	=	1.76 kg SO_2
3.8 GJ	x	204 g NO_x/GJ	=	0.78 kg NO_x
3.8 GJ	x	3.6 g CH/GJ	=	0.014 kg CH
3.8 GJ	x	5.8 g CO/GJ	=	0.022 kg CO
3.8 GJ	x	17.3 g Dust/GJ	=	0.066 kg Dust

The Institute for Paper Manufacture has ascertained the following values for waste water pollution /3/:

"CSB, kg/t /63/: 1.1 - 6.6 - 16.6
BSB_5, kg/t /53, 63/: 0.6 - 4.4 - 8.9"

The waste water from the manufacture of paper from bleached cellulose is polluted additionally with organic chlorine compounds. The level of this pollution of the waste water depends on the content of chlorine compounds in the cellulose and cannot be quantified in general at the moment.

The waste water pollution from the manufacture of papers containing waste paper is somewhat lower /3/.

The paper transportation of kraft paper from Sweden necessitates a primary energy requirement of 0.6 GJ/t, which is put in predominantly to produce electricity for the railway[1]. The emissions resulting as a consequence of this are given in Table 17.

Table 17:

Emissions during the production of electricity from fossil fuels in municipal power stations for the transportation of 1 t paper /30/.

Quantity of input Primary Energy	x	Emission Factor	=	Emission per t Paper
0.6 GJ	x	605 g SO_2/GJ	=	0.363 kg SO_2
0.6 GJ	x	293 g NO_x/GJ	=	0.176 kg NO_x
0.6 GJ	x	3 g CH/GJ	=	0.002 kg CH
0.6 GJ	x	13 g CO/GJ	=	0.008 kg CO
0.6 GJ	x	34 g Dust/GJ	=	0.020 kg Dust

The emissions occurring within the Federal Republic of Germany during the transportation of paper by lorry (0.3 GJ/t equivalent to 7 kg diesel fuel /t) are treated as equivalent to the emissions during the transportation of LDPE-granules, and can be taken from Table 7.

Total Damages

The total damages to air and water during the manufacture of paper (2.2.1 and 2.2.2) are summarised in Table 18.

Table 18:

Total damages to air and water during the manufacture of 1 t paper.

		Kraft Paper Bleached	Kraft Paper Unbleached	Sulphite Paper bleached
Air-polluting emissions		10.28 kg SO_2 5.41 kg NO_x 0.60 kg CH 1.66 kg CO 1.77 kg Dust		42.29 kg SO_2 7.61 kg NO_x 1.61 kg CH 14.33 kg CO 3.85 kg Dust
Waste Water pollution	CSB:	9.1 kg	67.6 kg	113.6 kg
	BSB_5	5.1 kg	25.4 kg	49.4 kg
	AOX	not applicable	3.5 kg	4 to 5 kg

1) Here again, for reasons of simplicity, the calculations are made using the production of electricity from fossil fuels.

3. CARRIER BAGS

3.1 Energy Consumption and Environmental Damage

The energy consumption for the manufacture of 50,000 carrier bags made from polyethylene film or paper is estimated to be 1 GJ. The energy required for this is drawn predominantly from the municipal concerns supplying energy, in the form of electricity. The emissions which arise from this are illustrated in Table 19.

Table 19:

Emissions during the production of electricity from fossil fuels in municipal power stations to manufacture 50,000 carrier bags /30/.

Quantity of input for 50,000 Carrier Bags	x	Emission Factor	=	Emission for 50,000 Carrier Bags
1 GJ	x	605 g SO_2/GJ	=	0.605 kg SO_2
1 GJ	x	293 g NO_x/GJ	=	0.293 kg NO_x
1 GJ	x	3 g CH/CJ	=	0.003 kg CH
1 GJ	x	13 g CO/CJ	=	0.013 kg CO
1 GJ	x	34 g Dust/GJ	=	0.034 kg Dust

In addition, the use of glue is necessary in the manufacture of paper carrier bags. The Institute for Paper Manufacture says the following about this /3/:

"The glueing of paper carrier bags requires glue based on starch or polyvinylacetate. The amount of glue necessary depends on the glue solution ratio (the concentration of glue) and, for starch, glue is between 1.5 - 2.7 kg glue (dry substance) per 1,000 sacks /71/. Owing to the larger capacity volume for sacks (for 50 L correspondingly longer lengthways seam) and the bottom seams on both sides, in comparison with a carrier bag, which has a content of 12 L, a glued seam of about double the length is necessary.

Accordingly, a glue consumption of 0.8 - 1.3 kg/1,000 pieces has to be put in for paper carrier bags. An energy requirement of 2 - 20 MJ has to be put in for the production of 1 kg of glue (starch glue or polyvinylacetate). At a weight of 30g per carrier bag, the additional energy requirement results in 0.07 - 0.7 GJ/t paper. An average of 0.3 GJ/t is put in to the total energetic assessment."

Because of the somewhat higher weight (36g instead of 30g) of the paper carrier bag taken into consideration in the following, the additional maximum energy requirement for glueing is lower (0.6 GJ/t paper instead of 0.7 GJ/t). However, the average value (0.3 GJ/t) ascertained by the Institute for Paper Manufacture is influenced by this only to an extent which can be ignored. This energy is put in in the form of electricity in the same way. The emissions arising at the same time from the production of electricity are summarised in Table 20.

Table 20:

Emissions during the production of electricity from fossil fuels in municipal power stations to glue 1 t paper for paper carrier bags /30/.

Quantity of input Primary Energy	x	Emission Factor	=	Emission per t Paper
0.3 GJ	x	605 g SO_2/GJ	=	0.182 kg SO_2
0.3 GJ	x	293 g NO_x/GJ	=	0.088 kg NO_x
0.3 GJ	x	3 g CH/GJ	=	0.001 kg CH
0.3 GJ	x	13 g CO/GJ	=	0.004 kg CO
0.3 GJ	x	34 g Dust/GJ	=	0.010 kg Dust

The colours used when printing carrier bags can contain a broad spectrum of substances. However, these are not fundamentally different in quality and quantity for polyethylene or paper, so that it is not necessary to contrast them within the framework of this comparison.

3.2. Material Requirement

In 1986 in the Federal Republic of Germany 59,097 t of carrier bags made from polyethylene and 8.059 t of carrier bags made from paper were manufactured /64/[1]. The Industrial Association for Paper and Plastic Packaging estimates the number of paper carrier bags manufactured from this to be 250 to 350 million and the number of polyethylene ones to be 2.5 thousand million (quoted in /3/). It would be possible to calculate from this the average weight of a carrier bag made of polyethylene or paper and manufactured in the Federal Republic of Germany. However, as the type and number of different carrier bags (small/large, stability, etc) are not known, this way of ascertaining the material requirement of comparable polyethylene and paper carrier bags is not suitable.

In the comparison on hand, common carrier bags from grocery shops and super markets which have the same suitability for use, are investigated (volume: 12 L, load-bearing capacity: 5 kg). The material requirement for such carrier bags amounts to approximately 0.4m^2 polyethylene film or paper. The thickness of the polyethylene film varies between 30 and 60 m. The average value of 50μm is put in for further calculations[2].

---

1) Over and above this, in 1986 184,438 t packets made from polyethylene and other plastics and 89,238 t paper packets (packets with a cross-over bottom, flat packets, packets with folds in the sides and bulk packets) were produced /39/.

2) Even with thinner films, the same load-bearing capacity can be achieved by the addition of LDPE-portions. (Compare 2 of this report.)

As a rule, it is necessary to use special kraft paper in order to manufacture comparable paper carrier bags. In grocery shops and supermarkets, you often come across paper carrier bags made from unbleached kraft paper. In contrast with this, the Institute for Paper Manufacture has ascertained /3/:

"According to information from the Industrial Association for Paper and Plastic Packaging, during the processing of paper carrier bags 60-65% bleached and 25% unbleached sulphate cellulose paper, as well as 10-15% bleached sulphite cellulose paper is used /65/. This raw material requirement is assumed for the total area of production, bags, packets, carrier bags (1986: 98,000t).

Thus, the following paper requirement is taken as a basis for the exclusive comparison of carrier bags:

60% kraft paper bleached (made from bleached sulphate cellulose)

25% kraft paper unbleached (made from unbleached sulphate cellulose)

15% sulphite paper bleached (made from bleached sulphite cellulose)."

Consequently, in the following not only carrier bags made from pure unbleached kraft paper will be taken into consideration, but also carrier bags based on the combination of paper mentioned above.

The material strength of the paper used - expressed through the surface weight - varies between 70 and 110 g/m^2. Whilst 70 g/m^2 kraft paper is used primarily for so-called bulk packets, as a rule carrier bags have a higher surface weight. For the purpose mentioned, carrier bags made from kraft paper with a surface weight of 90 g/m^2 are found in use most often.

Taking into consideration, the density of LDPE (0/92 g/cm^3), a polyethylene carrier bag with a film-strength thickness of 50 μm and a material surface of $0.4m^2$ weighs 18g. A comparable paper carrier bag made from paper, with a surface weight of 90 g/m^2 and a material consumption of $0.4m^2$ as well, weighs 36g. Consequently, the result is a weight ratio between polyethylene and paper carrier bags of 1 to 2.

Thus, for the manufacture of 50,000 carrier bags, a material input of 0.9 t is necessary, in the case of polyethylene, and 1.8 t in the case of paper. The energy required for this results from the values ascertained for polyethylene film and paper plus the values for manufacturing the carrier bags. These are summarised in Table 21.

Table 22 reproduces the environmental damage.

Table 21:

Energy consumption for the manufacture of 50,000 carrier bags.

	Polyethylene	Kraft Paper Unbleached	Paper Combinations
Energy			
For the manufcturing process	29 GJ	67 GJ	69 GJ
In the material	38 GJ	29 GJ	29 GJ
Total Energy consumption	67 GJ	96 GJ	98 GJ

Table 22:

Environmental damage from the manufacture of 50,000 carrier bags.

	Polyethylene	Kraft paper Unbleached	Paper Combinatons
Air-polluting emissions			
SO_2	9.9 kg	19.4 kg	28.1 kg
NO_x	6.8 kg	10.2 kg	10.8 kg
CH	3.8 kg	1.2 kg	1.5 kg
CO	1.0 kg	3.0 kg	6.4 kg
Dust	0.5 kg	3.2 kg	3.8 kg
Waste Water Pollution			
CSB	0.5 kg	16.4 kg	107.8 kg
BSB_5	0.02 kg	9.2 kg	43.1 kg
CH	0.003 kg	not applicable	not applicable
Phenol	0.0001 kg	not applicable	not applicable
AOX	not applicable	not applicable	5 kg

3.3. Waste Management

The waste management of polyethylene and paper carrier bags takes place, together with domestic waste, on disposal sites, in waste incineration plants and in plants for composting domestic waste. Furthermore, in the comparison of effects on the environment, the harm done to the environment by carrier bags thrown away after use into nature and the countryside - so-called "littering" - must be taken into consideration.

3.3.1 Disposal Sites

Paper contains organic substances which are biologically degradable. The decomposition should be brought to a conclusion within 30-50 years in well-run domestic waste disposal sites (bio-reactor disposal sites). The substances and compound substances which occur during decomposition are carried out by means of the water seeping into the ground and the gases from the disposal site. In addition to the organic products of decomposition, additives and the contents of paper carrier bags, e.g. heavy metals, are harmful to the water seeping into the ground.

In this way, paper carrier bags contribute considerably to emissions from disposal sites. The extent of this cannot be quantified. Furthermore, the decomposition of paper results in a change in structure, as well as a reduction of the mass. To this extent, paper carrier bags lead to settling on disposal sites which prevents reliable filling of the surface area. After about 30 to 50 years, the emissions into the water seeping into the ground and into the gases from the disposal site have abated to a large degree and can certainly be controlled.

Microbiologically, polyethylene decomposes with great difficulty. In this respect, polyethylene carrier bags do not make any contribution worth mentioning to the water seeping into the ground and the gases from disposal sites. With regard to the additives and contents of the bags, the same is valid here as for paper carrier bags.

Also, owing to the fact that hardly any decomposition takes place, polyethylene carrier bags make practically no contribution to settling on disposal sites.

In comparison with paper, polyethylene carrier bags contribute more towards the soiling of the vicinity of disposal sites in the operation of open disposal sites which are usual these days. This is caused by the bags being blown around by the wind and has a very adverse effect on the acceptability of the location of a disposal site.

Therefore, with regard to effects on the environment, paper carrier bags lead to additional damage to the water seeping into the ground and to emissions of gases. Polyethylene carrier bags do not have these effects on the environment. On the other hand however, the medium-term aim of operating the disposal site, is decomposition, in order to stabilise the disposal site and, later, to relieve it of after-care. In this respect, polyethylene carrier bags have disadvantages, although it is taken for granted that emissions arising and entering the water seeping into the ground and the gases will be reduced.

3.3.2 Waste Incineration

Polyethylene carrier bags have a somewhat higher calorific value than comparable paper carrier bags. However, for reasons of fundamental consideration, this does not result in an advantage for polyethylene carrier bags, because, as a rule, a further increase in the calorific value of waste is not desirable. At least, with older waste incineration plants, it leads to a reduction of the through-put

capacity, because the steam capacity for which the plant was designed must not be exceeded. Thus, from the point of view of waste management, an increase in the calorific value of waste should be rejected because, as a result of the reduced through-put capacity, waste has to be stored untreated. Consequently, in comparison with paper carrier bags, there is no way in which a positive assessment can be traced back to the higher calorific values of the plastics fraction.

With regard to the portion of heavy metal input into domestic waste incineration plants, which is determined primarily by the colour pigmentation, polyethylene and paper carrier bags are classified equally.

3.3.3. Composting

Paper from unbleached paper carrier bags without colour is a good raw material for composting if the material is torn up before rotting. Although paper carrier bags contribute to an increase in the C/N-ratio, this does not normally lead to a slowing down of the intensity of the rotting process owing to the low proportion of paper.

Polyethylene carrier bags cannot decompose biologically and, therefore, are not desirable in the rotting material. The necessary removal of plastic parts from ready-manufactured composts, for reasons of quality, is only possible through considerable technological expenditure. Printed colours on plastic bags separate from the bags during the rotting and are then found in the compost. In this way, through the use of printed colours containing heavy metals, the heavy metals can be carried into the compost. This applies in the same way to paper carrier bags. However, in recent years, the content of heavy metals in printing colours has reduced drastically.

Consequently, in the case of waste composting, a clear statement is possible : Paper is suitable as an initial material. In contrast, polyethylene is an unsuitable raw material for this process of waste management and causes disruption.

3.3.4 The Problem of Litter

The assessment of paper and polyethylene carrier bags is different, if one compares the results from improper waste management: If polyethylene carrier bags are used and then thrown away carelessly in the countryside or on a stretch of water, blown around or end up in open country in some other way, they lead to a considerably longer-term impairment of the appearance of the city, park or natural landscape than paper, because - as mentioned above - polyethylene carrier bags do not rot.

This impairment of the landscape cannot be quantified, but it should be mentioned.

4 Literatur

/ 1/ Herner, M. und H.-J. Wolter: Polyethylen niedriger Dichte (LDPE/LLDPE). Kunststoffe 77 (1987) Nr. 10, S. 959/962

/ 2/ Gondro, C.: Polyethylen hoher Dichte (HDPE). Kunststoffe 77 (1987) Nr. 10, S. 962/966

/ 3/ Göttsching, L., U. Hamm und H.-J. Putz: Gutachten über: Vergleich der Umweltverträglichkeit von Papier- und Polyethylentragetaschen und -säcke im Auftrag des Verbandes Deutscher Papierfabriken. Darmstadt November 1987

/ 4/ Kindler, H. und A. Nikles: Energiebedarf bei Herstellung und Verarbeitung von Kunststoffen. Chem.-Ing.Tech. 51 (1979) Nr. 11, S. 1125/1127

/ 5/ Kindler, H. und A. Nikles: Energieaufwand zur Herstellung von Werkstoffen - Berechnungsgrundsätze und Energieäquivalenzwerte von Kunststoffen. Kunststoffe 70 (1980) Nr. 12, S. 802/807

/ 6/ Pothmann, D.: Rohstoffe und Energie, in der Vortragsreihe "Anforderungen der Zukunft an die Herstellung von Papier". Wochenblatt für Papierfabrikation (1981) Nr. 2, S. 35/48

/ 7/ Ökobilanzen von Packstoffen. Herausgegeben vom Bundesamt für Umweltschutz, Schriftenreihe Umweltschutz Nr. 24 Bern, April 1984

/ 8/ Sundström, G.: Untersuchungen zum Berichtsentwurf des Umweltbundesamtes vom 09.10.1986 im Auftrag der Firma Scankraft, Malmö, 4.6. 1987.

/ 9/ Danninger, S.: Weißes Papier schmutzige Flüsse. Umweltschutz in Österreich (1987) Nr. 7/8, S. 14/18

/10/ Committee for the Golf of Bothnia: Report of the special working group, Water pollution problems of pulp and paper industries in Finland and Sweden, May 1987

/11/ National Environmental Protection Board, Action plan for marine pollution, Sweden May 1987

/12/ Background document for the "Action plan for marine pollution", persistent organic compounds in the marine environment, Sweden Sept. 1987

/13/ Sachtleben, T.R., agro consult: Mitteilung an das Umweltbundesamt vom 08.10.1987

/14/ Strahm, R.H. et al.: Jute statt Plastic-Dossier zur Verkäuferschulung. Jute-Aktion/Erklärung von Bern (o.J.)

/15/ Keiper, M., H. Haas und E. Bügner: Werkbuch Jute statt Plastik - eine Aktions- und Arbeitshilfe. Gepa, Aktion Dritte Welthandel, Mai 1983

/16/ Thalmann, W.R. und V. Humbel: Herstellung der Kunststoffe LDPE, HDPE, PVC und HIPS: Ökologische Bilanz-Betrachtungen. Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, St. Gallen, (im Auftrag des Bundesamtes für Umweltschutz), März 1985

/17/ Weissermel, K. und H.-J. Arpe: Industrielle organische Chemie. 2. überarbeitete und ergänzte Auflage Verlag Chemie (1978)

/18/ Arbeitsgemeinschaft Energiebilanzen: Energiebilanzen der Bundesrepublik Deutschland, Verlags- und Wirtschaftsgesellschaft der Elektrizitätswerke mbH (1985),

/19/ Gropper, H.: Polyolefine, Kapitel LD-Polyethylen, Ullmanns Encyklopädie der technischen Chemie 4., neubearbeitete und erweiterte Auflage Verlag Chemie, Band 19 (1980), S. 167/178

/20/ Davids, P., und M. Lange: TA Luft '86 - Technischer Kommentar. VDI-Verlag GmbH, Düsseldorf 1986

/21/ Fichtner:Der Beitrag ausgewählter neuer Technologien zur Rationellen Energieverwendung in der deutschen Industrie. Studie der Firma im Auftrag des Bundesministeriums für Forschung und Technologie, März 1986

/22/ Hauß, BASF Aktiengesellschaft: Mitteilungen an das Umweltbundesamt vom 17.01.1986

/23/ Winter, G.: Chemie und Erdöl, Swiss Chem 1 (1979) Nr. 7/8, S. 47/58

/24/ Umweltbundesamt: Emissionsfaktoren für den Hauptantrieb von großen Seeschiffen 1986 (unveröffentlicht)

/25/ Umweltbundesamt: Schwefelgehalt von Schiffsdieselölen (Bunkerölen) 1986 (unveröffentlicht)

./26/ Ruzicka, D.J., F. Robben und R.F. Sawyer: Optimization of a CFR Diesel Engine and Combustion of Heavy Fuels. Schiff und Hafen/Komandobrücke 38 (1986) Nr. 3, S. 55/62

/27/ Umweltbundesamt: Emissionsfaktoren in der Mineralölindustrie (1985) (unveröffentlicht)

/28/ Fünfundvierzigste Allgemeine Verwaltungsvorschrift über Mindestanforderungen an das Einleiten von Abwasser in Gewässern (Erdölverarbeitung) - 45. AbwasserVwV - vom 05.09.1984. GMBl 1984, S. 362

/29/ Umweltbundesamt: Abwassermengen aus Raffinerien 1986 (unveröffentlicht)

/30/ Umweltbundesamt: Emissionsfaktoren für öffentliche Kraftwerke zur Stromerzeugung 1985 (unveröffentlicht)

/31/ Hauß, BASF Aktiengesellschaft: Mitteilung an das Umweltbundesamt von 04.12.1987

/32/ Sechsunddreißigste Allgemeine Verwaltungsvorschrift über Mindestanforderungen an das Einleiten von Abwasser in Gewässer (Herstellung von Kohlenwasserstoffen) - 36. AbwasserVwV - vom 05.09.1984 GMBl 1984, S. 342/345

/33/ Umweltbundesamt: Emissionsfaktoren für die motorische Dieselkraftstoffverbrennung (LKW-Transport) 1986 (unveröffentlicht)

/34/ Baumgarten, H.L. und U. Welker, Papiertechnische Stiftung München: Mitteilung an das Umweltbundesamt vom 20.12.1985

/35/ Papier, Faserrohstoffe. Ullmanns Encyklopädie der technischen Chemie 4., neubearbeitete und erweiterte Auflage Verlag Chemie, Band 17 (1978), S. 531/576

/36/ Papier, Herstellung usw. Ullmanns Encyklopädie der technischen Chemie 4., neubearbeitete und erweiterte Auflage Verlag Chemie, Band 17 (1978), S. 577/635

/37/ Lundholm, M.P. und G. Sundström: Ressourcen- und Umweltbeeinflussung durch zwei Verpackungssysteme für Milch, Tetra Brik und Pfandflasche. Malmö 1986

/38/ Jäppinen, H. und J. Nills-Rämä: The role of possibilities of sulphate pulp industry in the abatement of emissions of sulphur and nitrogen compounds. EUCEPA-Symposium Environmental Protection in the 80's, Helsinki, 1986, zitiert nach / 3 /.

/39/ IFEU-Institut: Untersuchung des Altpapiermarktes und Verfolgung des Schadstoffpfades in der Altpapierverwertung. Im Auftrag des Ministeriums für Ernährung, Landwirtschaft und Forsten des Landes Baden-Württemberg, Stuttgart, 1986, zitiert nach / 3 /.

/40/ Fredriksson, R.: The technological potential for more efficient use of energy in industry. Energy Technology 1984. Herausgegeben vom National Swedish Board for Technical Development anläßlich der Hannover Messe, Hannover, 1984, zitiert nach / 3 /.

/41/ Reside, D.E., A.A., Roche, D.C. Bouchard und E. Muratore: Kraft Mill energy management. Pulp & Paper Canada 82 (1981) Nr. 11, T 382 - T 389, zitiert nach / 3 /.

/42/ Buekens, A.G. und J. Schoeters: Ohne Plastik weniger Kraft und Wärme. Entsorgungs-Praxis (1986) Nr. 5, S. 316 - 319, zitiert nach / 3 /.

/43/ Schmidt, F.E.: Analyse des Energieverbrauchs einer Sulfitzellstoffabrik. Wochenbl. f. Papierfabrikat. 107 (1979) Nr. 2, S. 44 - 50, zitiert nach / 3 /.

/44/ Gerken, A.: Der direkte Energieverbrauch der Papierherstellung, Wochenbl. f. Papierfabrikat. 105 (1977) Nr. 7, S. 213 - 222, zitiert nach / 3 /.

/45/ Winkler, E. und O. Wunderlich: Zellstoffgewinnung - Verfahrenstechniken (Sulfit- und Sulfatverfahren) und Emissionen luftfremder Stoffe. Haustechnik - Bauphysik - Umwelttechnik - Gesundheits-Ingenieur 101 (1980) Nr. 11, S. 324/332

/46/ Prahacs, S.: Air Quality Management. Miscellaneous Report No. MR 35, Pulp and Paper Research Institute of Canada, Point Claire, 1983, zitiert nach / 3 /.

/47/ Jensen, W.: Environmental Trends in the Finnish Pulp and Paper Industry. Paperi ja Puu 68 (1986) Nr. 5, S. 344 - 352, zitiert nach / 3 /.

/48/ Dallons, V.J. und Ch. Simons: Investigation of volatile organic compound emissions provides a data base for the industry. Tappi 65 (1982) Nr. 5, S. 67 - 70, zitiert nach / 3 /.

/49/ Melin, A.: The National Swedish Environment Protection Board: Mitteilung an das Umweltbundesamt vom 24.11.1987

/50/ Annergren, E., P. Lindblad, G. Carlsson und M. Norrby: Spent liquors from bleaching of softwood kraft pulps. Effect of chlorination variables on the content of lipophilic chlorinated organic matter with low molecular mass. EUCEPA-Symposium Environmental Protection in the 90's, Helsinki, 1986, zitiert nach / 3 /.

/51/ Stark, H.: Umweltschutz in der Zellstoff- und Papierindustrie. Papier aus Österreich (1987) Nr. 1, S. 15 - 22, zitiert nach / 3 /.

/52/ Strömdahl, I.: Environmental Demands on the Swedish Kraft Pulp Mills. Swedish Pulp and Paper Journal Nr. 2 (1986) S. 42 - 47, zitiert nach / 3 /.

/53/ Orivuori, J. und H. Siitonen: Estimate of the effluent treatment costs in the Finnish pulp and paper industry in 1980 - 1990 and their effect on the market price of the end-products. EUCEPA-Symposium Environmental Protection in the 90's, Helsinki, 1986, zitiert nach / 3 /.

/54/ Springer, A.M. und R.C. Peterson: Environmental Control. In Pulp and Paper Chemistry and Chemical Technology, Vol II, Herausgeber J.P. Casey, John Wiley & Sons Inc., 3. Auflage, New York, 1980, zitiert nach / 3 /.

/55/ Papier '87, Ein Leistungsbericht der deutschen Zellstoff- und Papierindustrie; Herausgegeben vom Verband Deutscher Papier e.V., Bonn, 1987

/56/ Umweltbundesamt: Emissionsfaktoren für die Sulfit-Ablaugenverbrennung 1986 (unveröffentlicht)

/57/ Umweltbundesamt: Emissionsfaktor für die Zellstoffherstellung ohne Ablaugenverbrennung 1986 (unveröffentlicht).

/58/ Pearson, G.: CPPA tour finds sulphite has grown to meet Central Europe's tough environment standards. Pulp & Paper Canada 86 (1985) Nr. 12, S. 13 - 14, zitiert nach / 3 /.

/59/ Scheuring, L.: Erfahrungen mit der Sauerstoffbleiche in einer deutschen Sulfit-Zellstoffabrik. Das Papier 40 (1986) Nr. 10A, S. V8 - V16, zitiert nach / 3 /.

/60/ Ducey, M.J.: German Sulfite Mills reduce Chlorine Bleaching due to new restrictions. Tappi 61 (1987) Nr. 7, S. 102 - 103, zitiert nach / 3 /.

/61/ Christmann, W., M. Erzmann und H. Irmer: Abwassersituation in der Zellstoffindustrie - Stand und Entwicklung der innerbetrieblichen und externen Vermeidungsmaßnahmen. WaBoLu Heft 2 1985, zitiert nach / 3 /.

/62/ Umweltbundesamt: Jahresbericht 1985, Abwasser aus der Zellstoffherstellung S. 111/112

/63/ Börner, F., H.-L. Dalpke, A. Geller und L. Göttsching: Ermittlung der Abwasserparameter zur Festlegung von Mindestanforderungen gem. § 7a WHG bei Sulfitzellstoffabriken und bei Papier- und Pappenfabriken. Forschungsbericht Wasser 102 06 031/06 im Auftrag des Umweltbundesamtes, Darmstadt, 1979, zitiert nach / 3 /.

/64/ Rationalisierungs-Kuratorium der Deutschen Wirtschaft (RKW) e.V.: Produktionsmenge und Produktionswert der Verpackungsindustrie in der Bundesrepublik Deutschland und Berlin (West) 1985 - 1986, 1987, S. 17/20

/65/ Mitteilungen vom Industrieverband Papier -und Plastikverpackung e.V., Frankfurt, zitiert nach / 3 /.