ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry

EFFECTS OF RECYCLED FIBER USE

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OVERVIEW OF EFFECTS OF RECYCLED FIBER USE

Introduction

Recovered fiber begins its life as virgin fiber, from harvested wood. Much of the virgin fiber that enters the paper fiber system, shown below, is used repeatedly before it is finally discarded. Sometimes recovered fiber is used to make the same product and sometimes it is moved to another point in the system where it is used to make a different product.

The types of fibers used by a mill are dictated by the product's performance requirements (brightness, absorbability, strength, etc.), cost considerations, the mill's processing equipment, and the customer’s needs.

Recycled fiber is not separate from the industry’s overall fiber system. The diagram below shows that the virgin fiber and recycled fiber systems are really part of a single wood fiber system. Recovered fiber would not exist if virgin fiber were not harvested, processed and placed into the wood fiber system. Likewise, with over 30% of the industry’s fiber coming from recovered paper, the industry would be hard pressed to meet the demand for its products without recovered fiber. Both are required. Virgin fiber is generally used in those applications where it provides needed strength, brightness or surface properties at a competitive cost. Likewise, the use of recovered fiber is dictated by considerations of price and performance in specific applications.

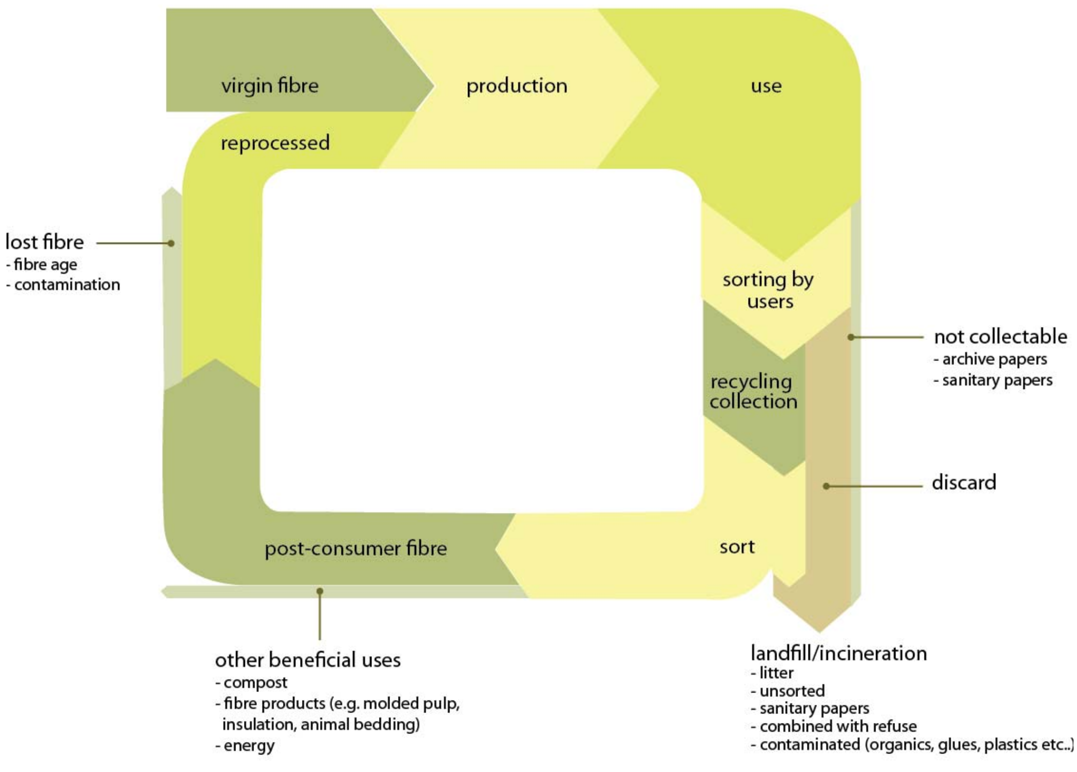

Figure R1 Generic Fiber System Illustrating Flow of Recovered Fiber (Source: Environment Canada 2011)

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Defining Paper "Recycling" vs. "Recovery"

To understand the environmental effects of paper recycling, it is necessary to understand the difference between paper "recovery" and paper "recycling." Paper is *recovered* when someone separates paper from other parts of the waste stream in a form that it allows it to be reused instead of discarded. Because the fate of non-recovered paper is often known (e.g., in the U.S. about 80% is landfilled) it is often possible to estimate the effects of recovering used paper by looking at the emissions that would have occurred if the material had be discarded instead of recovered.

Effects of Recovering and Recycling Paper

When recovered paper is used by paper or paperboard mills, we call it *recycling* (or in the industry's terminology, recovered paper utilization). The environmental effects of increased paper recycling by a company are much more difficult to know than the effects of overall used paper recovery. This is because there are many different competing uses for recovered paper. You need to ask yourself, "If I had not used this recovered paper, what would have happened to it?" This is often a difficult question to answer because, once recovered, used paper has many uses and is unlikely to be disposed of.

Many studies assume that the environmental effects of increased recycling include the effects of diverting material from disposal (i.e., recovery), but there are many circumstances where alternative assumptions may be equally valid, especially where recovery rates are approaching practical maximums and where exports are limiting the availability of recovered fiber for domestic use.

A report by Metafore (*The Fiber Cycle Technical Document*, available at http://postcom.org/eco/sls.docs/Metafore-Paper%20Fiber%20Life%20Cycle.pdf) explored the degree to which use of recovered fiber has been optimized in North America. The report found that

- the U.S. and Canada continue to increase recovery rates;
- recovered fiber is fully utilized;
- recovered fibers are fairly short-lived;
- different grades of paper utilize recovered fiber more efficiently than others but yield is reduced with every pass;
- increasing recovery is the key to improving the efficiency of the fiber cycle; and
- even at the highest possible recovery rate, the fiber cycle will continue to require significant inputs of virgin fiber to continue to produce paper.

In summary, the effects of increasing paper *recovery* are relatively clear because the alternatives to recovery are usually landfilling or burning. The effects of increased *recycling* for a particular use, however, are much less certain because there are many competing uses for recovered fiber and once recovered, the fiber is relatively unlikely to be discarded.

Questions related to the environmental aspects of recovering and recycling paper have led to a number of studies executed using the principles of life cycle assessment (LCA). NCASI has undertaken two reports that provide an overview of the methodological choices made in these studies, along with the implications of their selection when applied to the treatment of paper recycling within LCA (NCASI 2011, 2012). NCASI (2011) identifies seven overarching issues that drive the results of recycled fiber-related LCAs, or for which there is still too much uncertainty to fully understand their potential effect on LCA results:

1. impact of land use and alternative usage of the forest area;
2. the type of energy (i.e., fuel type and whether it is as power or heat) used during virgin and recovered fiber processing;
3. the type and amount of energy displaced when burning waste paper;
4. current capabilities of toxicity-related modeling for LCA impact indicators;

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5. assumptions regarding the degree of paper degradation in landfills and the approach used for modeling of biogenic carbon dioxide;
6. the selected allocation procedure for recycling, in cases where virgin and recycled paper are compared; and
7. recycled-to-virgin fiber substation ratio.

Overall, the existing knowledge on LCA and paper recycling does not allow for general conclusions to be made regarding the environmental superiority of using recycled or virgin fiber for paper production.

Industry Performance

The industry has continued to encourage increased paper recovery, and to optimize the use of that fiber in its overall fiber system. In both the U.S. and Canada, paper recovery rates have steadily grown over time, as shown in the charts below.

The industry has placed increased focus on recovering waste material from recycling processes to generate other products. Traditional management has been to landfill these materials, but research and practice with alternatives are increasing. Old corrugated container rejects are most commonly used as fuel, particularly in mill power boilers that have been designed for traditional solid fuels. These rejects are also burned in municipal or commercial energy facilities and have been employed as a fuel pellet ingredient. For plastic rejects, the predominant beneficial uses are in wood-plastic composite lumber and in fuel pellets. NCASI has published a report on these beneficial uses (NCASI 2000).

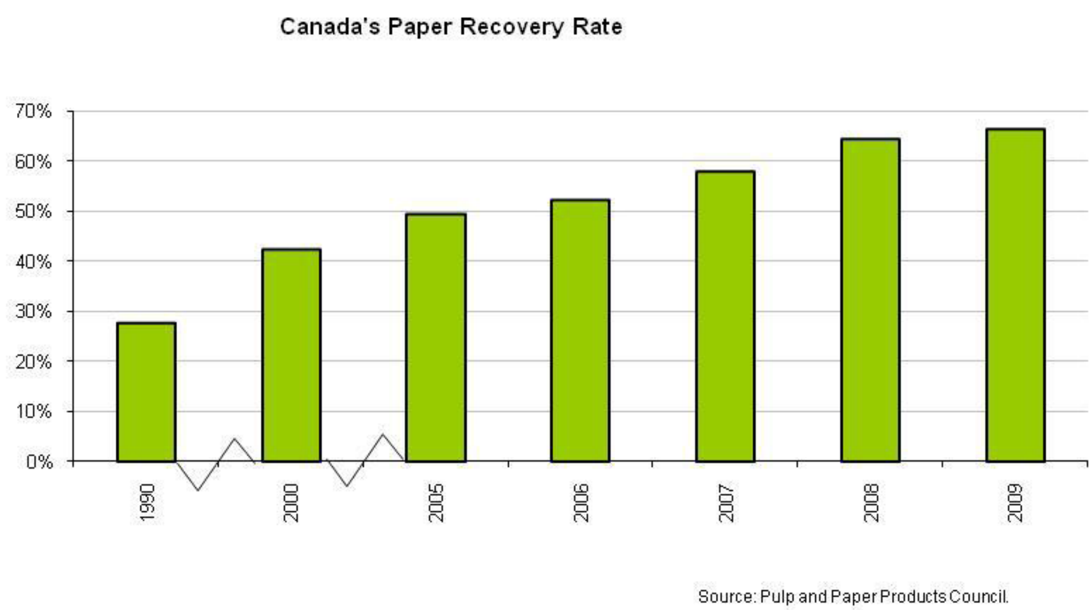

Figure R2 Canada's Paper Recovery Rate
(Source: Pulp and Paper Products Council as cited in FPAC 2012;
http://www.fpac.ca/publications/FPAC-Recycling_and_Fibre_Cycle-White_paper_FINAL.pdf)

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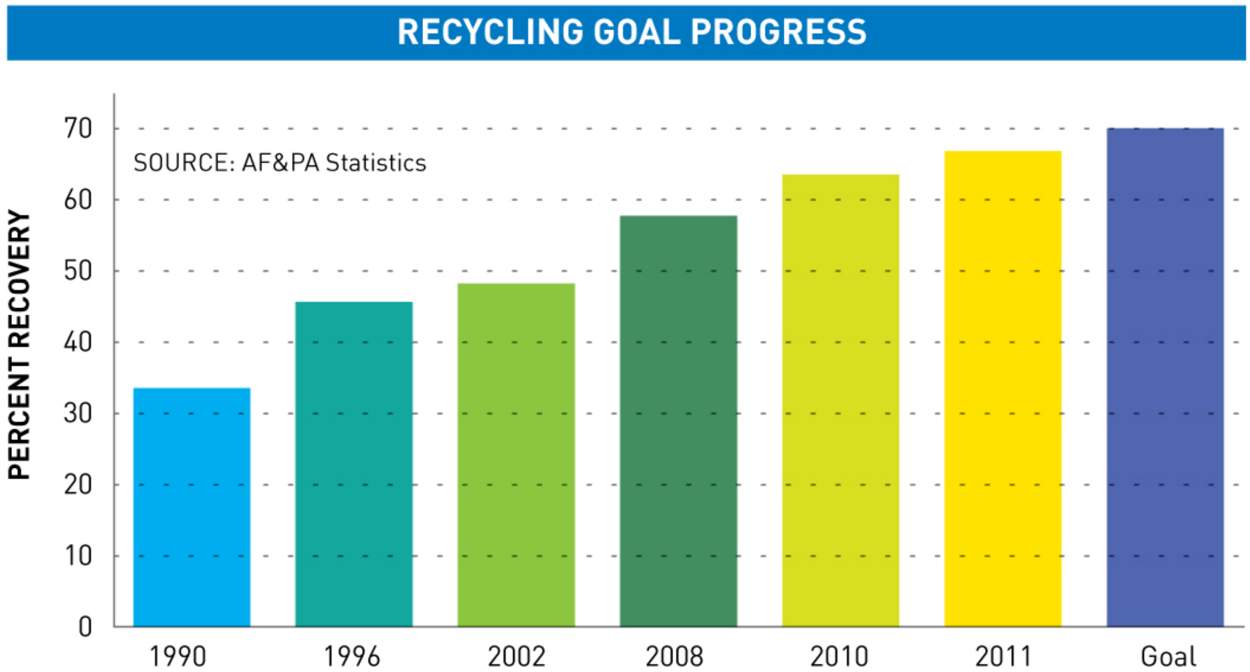

Figure R3 U.S. Paper Recovery Rate and AF&PA Recycling Goal
(Source: AF&PA 2012; http://www.afandpa.org/docs/default-source/default-document-library/2012-af-amp-pa-sustainability-report.pdf?sfvrsn=0)

Opportunities for Improvement

It is sometimes assumed that increased recycling creates a new demand for recovered fiber that, in turn, results in increased recovery. Whether this is true depends on a number of things. For instance, for several types of recovered fiber (e.g., old corrugated containers and old newsprint) the recovery rates are approaching practical limits (between 70% and 80% is recovered). This means that there is essentially a relatively stable pool of these types of recovered fiber, and if more is used in one type of product there will probably be less used in another type of product. This is especially true nowadays, where recovered paper exports from North America have grown to such an extent that an increase in paper recovery actually does not make more recycled paper available for domestic consumption. That said, the industry continues to seek opportunities to increase recovery of all types of paper, and continues to integrate recovered fiber into the supply chain.

Challenges to Increasing Recovery and Recycling

Foreign demand for recovered fiber from the U.S. has increased significantly in recent years, increasing competition for the resource. The fraction of paper and paperboard recovered for reuse in the U.S. nearly doubled between 1990 and 2012, to roughly 65%, but exports of recovered paper to China and other nations absorbed 41% of the paper collected for recycling in the U.S. in 2012, according to the American Forest and Paper Association (AF&PA); http://paperrecycles.org/statistics/where-recovered-paper-goes. This export rate continues to be a significant challenge in terms of ensuring a strong domestic source of recovered fiber for recycled paper mills in North America.

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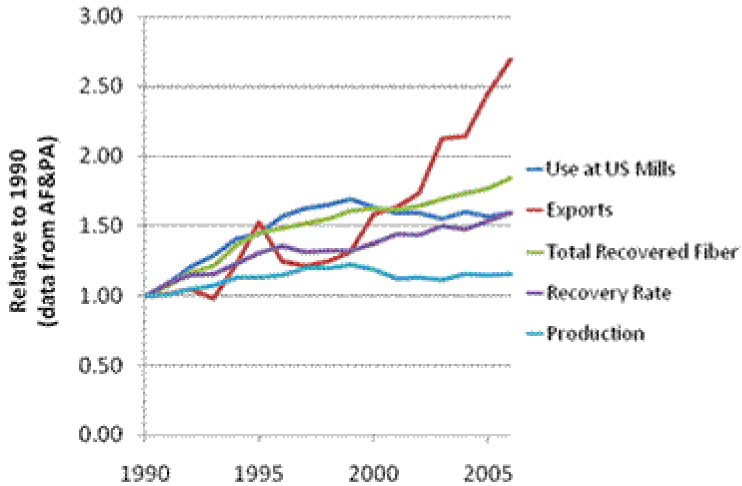

Figure R4 Recovered Fiber Trends
(Source: AF&PA)

Municipal paper recovery programs continue to expand in North America. The increased introduction of "single stream" recovery programs has, however, led to technical challenges for the industry in terms of reducing the relative recovery of usable fiber. Financial challenges for smaller communities in establishing effective paper recovery programs continue to limit paper recovery to larger population centers and locations where transportation of recovered fiber to paper mills is not prohibitively expensive.

Information on fiber recovery and use is available from the American Forest and Paper Association (AF&PA) at http://paperrecycles.org/statistics and from the Forest Products Association of Canada (FPAC) at http://www.fpac.ca/publications/FPAC-Recycling_and_Fibre_Cycle-White_paper_FINAL.pdf.

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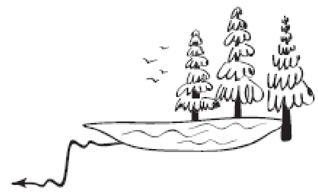

EFFECTS OF RECYCLED FIBER USE ON WATER USE

Overview

In general, mills that use only recovered fiber require less water to manufacture a specific type of product than those mills that manufacture the product from on-site produced virgin fiber. The effects need to be examined on a product-by-product basis, however.

For instance, the differences in water use and effluent flow between virgin and recycled linerboard mills are much greater than the differences between virgin and recycled newsprint mills (where NCASI data suggest no significant difference).

In addition, in some product sectors (linerboard and newsprint, for instance), many mills use a combination of virgin and recycled fiber. At these mills, the water systems in the "virgin" and "recycled" parts of the mill may be interconnected, making it difficult to generalize about the effects of increased recycling.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Paperboard

Containerboard

Recycled paperboard

Newsprint

Tissue

Fine paper

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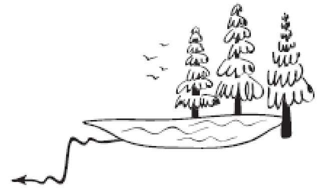

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EFFECTS OF RECYCLED FIBER USE ON WATER USE

Paperboard Sector

There are many types of paperboard, but the main division is between containerboard and recycled paperboard. Both containerboard and recycled paperboard contain large amounts of recycled fiber.

Containerboard is used in corrugated boxes. The outside layers of the corrugated material are made of a fiber sheet called linerboard or test liner and the middle fluted layer is called corrugating medium, medium, or fluting. Therefore, containerboard is often divided into two groups, liner and medium. Within the containerboard sector, product specifications vary and these specifications may affect the use of recovered fiber as well as the extent of mill water use and effluent volumes.

Water use and effluent flows at containerboard mills with virgin pulping on site are usually larger than at mills using only recovered fiber. At mills producing containerboard from a combination of on-site-produced virgin fiber and recovered fiber, a common situation in North America, production-normalized water use and effluent flow tend to fall between all-virgin and all-recycled mills. For more detailed information on containerboard mills, click here.

The opportunities to increase the use of recovered fiber use in recycled paperboard manufacture are very grade-dependent. In some cases, the product niches filled by recycled paperboard can be filled only by mills producing board from 100% recovered fiber, so there are no recycled fiber-related environmental footprint decisions to consider. In some cases, however, recycled paperboard and solid bleached sulfate (paperboard made from virgin bleached kraft pulp) compete in the same product niche. In other cases, recycled paperboard may compete against unbleached kraft board grades. Recycled paperboard mills usually use and discharge less water than bleached and unbleached kraft mills. For more specific information on some of the recycled fiber-related environmental footprint decisions involving recycled paperboard mills, click here.

There are additional, non-environmental considerations associated with increased recycling that customers may want to discuss with suppliers. To view a list of some of these, see the general overview section.

Additional information on the fiber quality requirements for paperboard manufacturing can be found in Gottsching and Pakarinen 2000.

More information on the sources of fiber in containerboard and recycled paperboard mills in the U.S. is available in the AF&PA “Recovered Paper Statistical Highlights” series (AF&PA n.d.). Comparable information from other countries is usually available from the country’s paper industry trade association.

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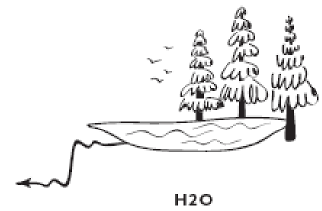

EFFECTS OF RECYCLED FIBER USE ON WATER USE

Containerboard Sector

Mills with virgin pulp production vs. 100% recycled containerboard mills

This section explains that, in general, mills producing containerboard from only recovered fiber have effluent flows that are lower than mills that have virgin pulp mills on site. This finding, supported in the published literature, is confirmed by statistical analysis of NCASI data, which includes site-specific information from mills across North America.

Effluent flows from mills with virgin pulping, especially kraft pulping, are usually larger than those from mills using only recovered fiber. Some of the published values for representative effluent flows from virgin and recycled containerboard production are shown in the following table. NCASI site-specific data suggest that production-normalized flows from virgin mills using large amounts of recovered fiber will be between those of all virgin and all recycling mills.

Table R1.

Mill Description	Effluent Flow (m^3/tonne)	Reference
Typical unbleached kraft mills	20 to 60	Springer 2000 Gottsching and Pakarinen 2000
Recycled liner, fluting	0 to 10	
Unbleached kraft pulp mills using Best Available Techniques	15 to 25	EC BREF 2001
Recycled board mills using Best Available Techniques	< 7	
Typical virgin containerboard mills (weighted average of linerboard and medium mills)	45	Paper Task Force 2002
Typical recycled containerboard mill	8	
Average unbleached kraft mill (1990)	49	USEPA 1993 draft technical development document
Average semi-chemical pulping mill (1990)	22	

The differences between virgin and recycled effluent volumes depend on the type of containerboard grade

This section explains that virgin linerboard mills generally use more water than virgin semi-chemical medium mills so the effects of increasing recycled content on water use and effluent flow will be different for linerboard and medium.

Unbleached kraft mills producing linerboard tend to use and discharge more water than semi-chemical pulping mills producing corrugating medium. This is in part because semi-chemical pulping mills often include higher fractions of recovered fiber in the furnish. In addition, however, virgin semi-chemical operations tend to discharge less water than virgin kraft pulping operations. In the early 1990s, USEPA reported the average effluent volume from unbleached kraft mills at 48.6 m^3/tonne while the average from

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semi-chemical pulping mills was 21.5 m^3/tonne (USEPA 1993). As a result, increasing the recycled content of corrugating medium will likely have less of an impact than increasing the recycled content of linerboard.

There are also different grades of linerboard, differing most notably in the basis weight (i.e., the weight per unit area) of the linerboard sheet. While the specifications associated with the different grades may affect the ability of individual mills to reduce water use, there is no published information indicating that the water use and effluent flow benefits associated with increasing recycled content of linerboard are a function of the grade of the linerboard.

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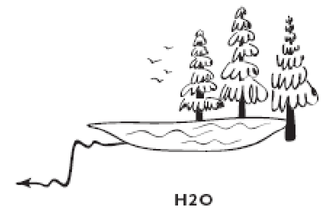

EFFECTS OF RECYCLED FIBER USE ON WATER USE

Recycled Paperboard Sector

In many segments of the recycled paperboard sector, mills use little, if any, virgin fiber. Recycled fiber-related environmental footprint decisions exist, therefore, only in a few categories where the same general product type can be made using significant amounts of virgin fiber.

This section explains which types of products that are made from recycled paperboard are also commonly made from paperboard containing significant amounts of virgin fiber. It is only in these product segments that recycled fiber-related paperboard sector environmental footprint decisions need be considered.

Recycled paperboard is used for packaging and other uses. In most of the “other” uses, such as tube stock (used to make paper tubes or cores) and gypsum board (used to line gypsum wall panels), the products are made only from recycled fiber. Among the packaging products, a few are wholly or primarily made from virgin fiber – food-grade liquid container packaging, for instance. There are, however, several products that are made from paperboard where the virgin fiber content can range from zero to 100%. Table R2, taken from material assembled by the Finnish Paper Engineers Association, summarizes the

Table R2. (Source: Paulapuro 2000)

Product	Typical Board Grades	Description of Fiber Content
Direct food	Folding boxes	Primary virgin fiber
Frozen food	Solid bleached sulfate	Virgin fiber
	Solid unbleached sulfate	Has significant virgin fiber content
Indirect food	White lined chipboard	Primary recovered fiber
Confectionary	Folding boxboard	Primarily virgin fiber
	Solid bleached sulfate	Virgin fiber
Bottle Carriers	Solid unbleached sulfate	Has significant virgin fiber content
Cosmetic, toiletries	Folding boxboard	Primarily virgin fiber
	Solid bleached sulfate	Virgin fiber
Cigarettes, tobacco	Solid bleached sulfate	Virgin fiber
	Folding boxboard	Primarily virgin fiber
Pharmaceuticals	Folding boxboard	Primarily virgin fiber
	White lined chipboard	Primary recovered fiber
Detergents	White lined chipboard	Primary recovered fiber
	Solid unbleached sulfate	Has significant virgin fiber content
Household durable, hobby items	White lined chipboard	Primary recovered fiber
Textiles, clothing, footwear	White lined chipboard	Primary recovered fiber
	Folding boxboard	Primarily virgin fiber
Toys, games	White lined chipboard	Primary recovered fiber
	Solid unbleached sulfate	Has significant virgin fiber content
Paper products	White lined chipboard	Primary recovered fiber
Milk, juices	Liquid paperboard packaging	Primarily virgin fiber

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major uses for paperboard packaging where recycled paperboard competes with board containing significant amounts of virgin fiber. The information in the table should be used with caution, however, because the table does not reflect a large number of situations where product characteristics and furnish quality are tailored to meet the requirements of specific applications.

In general, mills producing paperboard only from recycled fiber use and discharge less water than those making competing products from virgin fiber (assuming that the virgin fiber is produced on site).This finding is confirmed by statistical analysis of NCASI site-specific data.

Table R3 summarizes published data on the effluent discharges from recycled paperboard mills, unbleached kraft (sulfate) mills, and bleached kraft (sulfate) mills. The information makes it clear that while there is significant variability among mills, those producing recycled paperboard have lower effluent flows than those producing paperboard from virgin pulp.

Table R3.

Mill Description	Effluent Flow (m^3/tonne)	Reference
Typical unbleached kraft mills	20 to 60	Springer 2000
Recycled paperboard	0 to 15	Gottsching and Pakarinen 2000
Unbleached kraft pulp mills using Best Available Techniques	15 to 25	EC BREF 2001
Recycled board mills using Best Available Techniques	< 7	
Typical virgin unbleached kraft mills making coated unbleached paperboard	46	Paper Task Force 2002
Typical virgin bleached kraft mills making solid bleached sulfate paperboard	90	
Typical recycled paperboard mill	8	

Other considerations regarding paperboard mills

Some of the non-environmental issues that may accompany attempts to increase recycled content include the following.

- The potential impact of recycled fibers on strength properties
- The potential impact of recycled fibers on product appearance and odor
- Operational problems that occur at very low levels of discharge
- Operational problems, such as stickies (tacky substances that can deposit on papermaking equipment), that are associated with some grades of recovered fiber.

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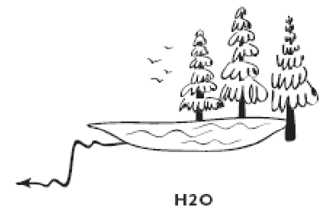

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Tissue Sector

A discussion of the effects of recycled fiber on tissue properties is beyond the scope of this Tool. The reader should consult with tissue manufacturers to better understand the constraints on fiber furnish that may be associated with the manufacture of products with specific properties.

Where tissue is manufactured at mills with virgin pulping, the most common virgin pulps produced are bleached kraft (sulfate) and bleached sulfite, although few bleached sulfite mills remain. Therefore, the co-benefits and trade-offs examined in this section compare recycled tissue manufacturing with tissue manufactured from virgin bleached kraft pulp.

The available literature suggests that water use and effluent flows from deinked tissue mills will be significantly lower than those from bleach kraft mills manufacturing tissue. This is confirmed by statistical analysis of NCASI data.

Table R5.

Mill Description	Effluent Flow (m^3/tonne)	Reference
Bleached kraft (sulfate) pulp production plus tissue manufacture	50 to 90 (sum of pulp and paper values)	Springer 2000
Deinked pulp production plus tissue manufacture	30 to 60 (sum of pulp and paper values)	Gottsching and Pakarinen 2000
Recycled newsprint mills	8 to 10	
Bleached kraft (sulfate) pulp mills using Best Available Techniques	30-50	EC BREF 2001
Deinked tissue mill using Best Available Techniques	8-25	

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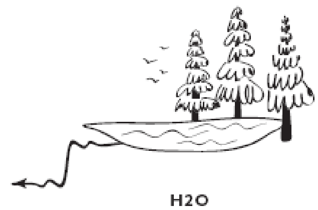

EFFECTS OF RECYCLED FIBER USE ON WATER USE

Fine Paper Sector

The fine paper sector includes a large number of product types. The product most commonly examined for environmental footprint trade-offs with respect to recycling is office paper (also known as copy paper or, in the industry's terminology, uncoated free sheet). This section, therefore, focuses on uncoated free sheet/copy paper.

Where fine paper is manufactured at mills with virgin pulping, the most commonly produced virgin pulp is bleached kraft (sulfate). Therefore, the co-benefits and trade-offs examined in this section compare recycled copy paper manufacturing with copy paper manufactured from virgin bleached kraft pulp.

A number of mills can produce both virgin pulp and recycled pulp for use in copy paper. Therefore, in many situations, increasing recycled content will require examination of how the increase affects the water reuse practices at specific mills. The available literature suggests, however, that in general, water use and effluent flows from deinked copy paper mills will often be significantly lower than those from bleached kraft mills manufacturing copy paper. This is confirmed by statistical analysis of NCASI site-specific data.

Table R6.

Mill Description	Effluent Flow (m3/tonne)	Reference
Bleached kraft (sulfate) pulp production plus coated fine paper manufacture (no number presented for uncoated fine paper)	60 to 100 (sum of pulp and paper values)	Springer 2000
Deinked pulp production plus coated fine paper manufacture (no number presented for uncoated fine paper)	40 to 70 (sum of pulp and paper values)	Gottsching and Pakarinen 2000
Recycled newsprint mills	10 to 20	
Bleached kraft (sulfate) pulp mills using Best Available Techniques	30 to 50	EC BREF 2001
Deinked mill using Best Available Techniques	18 to 15	
Typical virgin copy paper mill	86	Paper Task Force 2002
Typical recycled copy paper mill	43	

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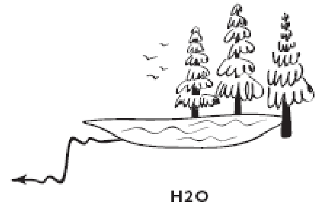
ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry



EFFECTS OF RECYCLED FIBER USE ON WATER USE

Newsprint Sector

A large and growing number of grades of printing and writing paper are made primarily from mechanical pulp. These are explained in Paulapuro (2000). Roughly half of the recovered old newspapers used for papermaking, however, are used to produce newsprint. Therefore, this section focuses on the co-benefits and trade-offs related to water use and effluent flows, when recycled newsprint is used in place of virgin mechanical pulp. *The information below may apply to other grades of paper made from mechanical pulp, but this should not be assumed true unless confirmed by more grade-specific information.*

Many mills now have facilities for producing both virgin mechanical pulp and recycled pulp from old newspapers (ONP). Therefore, in many situations, increasing recycled content will require examination of how the increase affects the water reuse practices at specific mills.

In any event, as the published information in the table below illustrates, there is significant overlap in the range of effluent flows for virgin mechanical newsprint and recycled newsprint mills. Therefore, in general, one would not expect that increasing recycled content of newsprint would have a significant effect on water use or effluent volumes. This is confirmed by statistical analysis of NCASI site-specific data.

Table R4.

Mill Description	Effluent Flow (m^3/tonne)	Reference
Mechanical pulp production plus newsprint manufacture	16 to 40 (sum of pulp and paper values)	Springer 2000 Gottsching and Pakarinen 2000
Deinked pulp production plus newsprint manufacture	20 to 45 (sum of pulp and paper values)	
Recycled newsprint mills	7 to 23	
Mechanical pulp mills using Best Available Techniques and using at least 50% mechanical pulp	12 to 20	EC BREF 2001
Recycled newsprint mill using Best Available Techniques	8 to 15	
Typical virgin newsprint mill	59	Paper Task Force 2002
Typical recycled newsprint mill	55	

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EFFECTS OF RECYCLED FIBER USE ON ENERGY USE

Overview

Recycling mills generally require less total energy (considering both the fuel used at the mill and purchased electricity) than mills with virgin pulping.

A somewhat different picture emerges when considering fossil fuel requirements rather than total energy demand. Differences in fossil fuel use (at the mill and associated with purchased electricity) are much smaller. Except perhaps for newsprint, the differences between virgin and recycling mill fossil fuel use are probably not significant.

Energy is required to collect and transport wood to virgin mills and recovered paper to recycled mills. On average, these energy requirements are much lower than the energy used in the manufacturing processes. Site-specific circumstances will determine whether more or less energy is required to collect and transport wood compared to recovered paper.

Finally, the results of overall energy comparisons between virgin and recycled products depend on the end-of-life management of non-recycled products (see link to “Energy Recovery from Discarded Forest Products”). For instance, if the “virgin” production system were to incorporate burning of used paper products with energy recovery (rather than recycling or landfilling), the differences in total energy use between the overall “virgin” and “recycled” systems would be reduced, although usually not eliminated. In a system where used paper is burned with energy recovery, there is typically lower fossil fuel energy demand than there would be for a recycling-based system.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry’s fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Energy use in manufacturing

Transportation energy

Energy recovery from discarded products

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EFFECTS OF RECYCLED FIBER USE ON ENERGY USE

Energy Use in Manufacturing

Seemingly similar mills can have very different energy requirements. It is not unusual for the “best” and “worst” mills within a given production category to have energy requirements that differ by a factor of two (Paprican 2005). Nonetheless, in general, mills that produce paper or paperboard from recovered fiber use less total energy, considering fuel use and purchased power, than mills making similar products from virgin fiber. This is to be expected since much of the energy used by virgin mills is required to separate wood into individual fibers—a process requiring much more energy than separating recovered paper into individual fibers.

On the other hand, because chemical pulp mills derive a large fraction of their energy from biomass fuels, published studies often conclude that they use less fossil fuel energy than recycling mills making comparable products.

Data from a number of studies are summarized in the following table and illustrate that the differences in fossil energy are often very small, especially considering the differences expected between individual mills. It is important to note that the values in the table include both the fuel used at the mill and the fuel required to produce purchased electricity.

Table R7.

Product and Process Description	Total Manufacturing Energy Requirements*	Fossil Energy Requirements in Manufacturing*	Reference
Virgin newsprint	37.1 MMBtu/ton	25.1 MMBtu/ton	Paper Task Force (2002)
Recycled newsprint	19.8 MMBtu/ton	15.5 MMBtu/ton	
Recycled newsprint	5 to 19 MMBtu/ton less than virgin newsprint		Five studies reported in Denison (1996)
Virgin corrugated boxes	26.7 MMBtu/ton	12.0 MMBtu/ton	Paper Task Force (2002)
Recycled corr. boxes	17.9 MMBtu/ton	14.6 MMBtu/ton	
Virgin office paper	37.6 MMBtu/ton	13.4 MMBtu/ton	Paper Task Force (2002)
Recycled office paper	20.1 MMBtu/ton	15.6 MMBtu/ton	
Virgin coated unbleached board	27.4 MMBtu/ton	10.9 MMBtu/ton	Paper Task Force (2002)
Virgin bleached board	39.3 MMBtu/ton	13.6 MMBtu/ton	
Recycled paperboard	15.9 MMBtu/ton	12.1 MMBtu/ton	

*Includes fuel used at the mill and the fuel required to produce purchased power.

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EFFECTS OF RECYCLED FIBER USE ON ENERGY USE

Transportation Energy

Transportation distances related to fiber procurement and product delivery vary enormously. Wood, pulp, and recovered paper are now routinely shipped half way around the globe. Therefore, to understand whether increased recycling causes significant increases in transportation energy consumption, it is necessary to understand the relative distances and modes of transport involved in bringing additional recovered fiber to specific mills. If the transportation distances for virgin fiber and additional recovered fiber are greatly different, the impact of transportation-related energy can be significant to the overall energy implications of increased recycling. Put another way, the assumption of "typical" transportation distances can yield misleading results in judging the effects of specific efforts to increase recycling.

One study that attempted to use typical transportation distances in the U.S. found that the energy required for collecting and transporting virgin fiber (1.2 to 1.9 MMBtu/ton paper produced) was not significantly different from the energy required to collect, process and transport wastepaper (1.5 MMBtu/ton paper produced) (Paper Task Force 2002). These energy requirements are small compared to those for manufacturing (10 to 40 MMBtu/ton) discussed in the Energy Use in Manufacturing section. It is important to repeat, however, that these "typical" results can mask site-specific circumstances where transportation-related energy requirements might be much more significant. Those wanting to understand the energy implications of specific recycling initiatives will need information that allows them to judge the potential significance of transportation energy. In specific, it will be necessary to know the likely distances involved in bringing additional recovered fiber to mills.

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EFFECTS OF RECYCLED FIBER USE ON ENERGY USE

Energy Recovery from Discarded Forest Products

Used paper has a significant fuel value—10 to 17 MMBtu/ton (USEPA 2006) or one-half to three-quarters or more of the fuel value of coal. As a result, the effects of increased recycling on overall energy consumption depend on whether the recovered paper would otherwise have been burned for energy and whether this is considered an offset to energy used elsewhere in the value chain.

Several studies have examined the total energy requirements for systems involving paper recycling compared to systems where recovered paper is burned for energy. Finnveden and Ekvall (1998) analyzed seven European life cycle studies of paper packaging materials covering 26 scenarios and found that in all cases, the total life cycle energy for recycling was less than that for burning used virgin paper as a fuel. Denison (1996) examined three U.S. studies and found that from a total energy standpoint, burning virgin paper for energy was preferable to landfilling but burning for energy still had a higher total overall energy requirement (by 3 to 10 MMBtu/ton of recovered paper) than a system where the paper was recycled. The Paper Task Force (2002) came to similar conclusions, finding total energy benefits of 3 to 17 MMBtu/ton of recovered paper for recycling vs. burning virgin paper for energy.

If, however, one is interested in fossil fuel-related energy instead of total energy, the situation is far less straightforward. In the studies examined by Finnveden and Ekvall (1998), 18 scenarios found lower fossil fuel use for systems where used paper was burned for energy, while eight found lower fossil fuel use in systems where used paper was recycled. In comparing the studies, they found that the results depended primarily upon assumptions about what type of fuel was displaced by the paper-based fuel. Where paper-based fuel was assumed to displace fossil fuel, this was found to require less fossil fuel than a system involving paper recycling. Otherwise, the recycling system was found to have lower fossil fuel use. The Paper Task Force (2002) study assumed that paper-based fuel would displace fossil fuels. Except for the case of newsprint, the fossil fuel-related energy required for the system involving recycling had fossil fuel requirements that were 6 to 9 MMBtu/ton of recovered paper greater than the system wherein used paper was burned for energy. In the case of newsprint, recycling and burning for energy required approximately equal amounts of fossil fuel.

Generally speaking, burning used paper for energy has been found to reduce total (life cycle) energy requirements compared to landfilling, but total energy requirements have tended to be higher than in a system where used paper is recycled. On the other hand, life cycle fossil fuel use has frequently (although not always) been found to be lowest for systems where used paper is burned for energy as long as the paper-based fuel displaces fossil fuels. NCASI (2011) undertook a review of 17 studies that compared waste management options for paper and noted that environmental analyses of recovery for recycling over burning for energy have not produced findings that can be generalized, primarily due to this question's sensitivity to key issues such as

1. impact of land use and alternative usage of the forest area;
2. the type of energy (i.e., fuel type and whether it is used as power or heat) used during virgin and recovered fiber processing;
3. the type and amount of energy displaced when burning waste paper;
4. current capabilities of toxicity-related modeling for LCA impact indicators;
5. assumption regarding the degree of paper degradation in landfills and the approach used for modeling of biogenic carbon dioxide;
6. the selected allocation procedure for recycling, in cases where virgin and recycled paper are compared; and
7. recycled-to-virgin fiber substation ratio.

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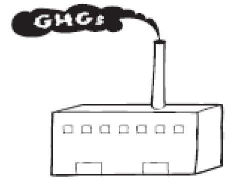

GREENHOUSE GASES

EFFECTS OF RECYCLED FIBER USE ON GREENHOUSE GAS EMISSIONS

Overview

Assessments of the effects of recycling on greenhouse gas emissions must, at a minimum, address impacts on:

a. fossil fuel-related greenhouse gas (GHG) emissions from manufacturing and along the value chain,
b. carbon sequestration in forests, products and landfills,
c. methane emissions from landfills,
d. avoided emissions associated with the burning used paper as biomass fuel, and
e. the likely alternatives to recycling for used paper.

The significance of these elements of the assessment will be very site-specific. In addition, some of the most important aspects of the assessment are very uncertain. It is, therefore, possible to calculate overall impacts of increased recycling on GHG emissions that range from highly beneficial to highly detrimental depending on site-specific circumstances and the assumptions used in the analysis.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Fossil fuel-related greenhouse gas emissions from manufacturing and along the value chain

Carbon sequestered in forests, products and landfills

Methane emissions from landfills

Fossil fuel-related emissions avoided through use of paper-derived fuels

Overview of two significant studies of the U.S. situation

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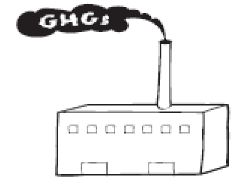

GREENHOUSE GASES

EFFECTS OF RECYCLED FIBER USE ON GREENHOUSE GAS EMISSIONS

Fossil Fuel-Related Greenhouse Gas Emissions from Manufacturing and Along the Value Chain

Of the various elements of this analysis, the emissions associated with fossil fuel use are best understood, in terms of currently available data. Even here, however, there are significant uncertainties. These uncertainties derive in part from factors that affect greenhouse gas (GHG) emissions but are independent of whether mills are virgin- or recycling-based, such as fuel choice or geographical location in the case of purchased power. In addition, different studies are based on different data sets and use different boundary conditions (in particular, some studies include emissions from purchased power while others do not).

A number of published studies suggest that, except for newsprint mills, most virgin mills have somewhat lower GHG emissions than recycled paper mills making similar products. In the case of newsprint, published studies often report that recycling mills have lower GHG emissions than virgin mills, especially if you also consider indirect emissions associated with purchased power production.

NCASI's analysis of site-specific mill emissions data, excluding emissions associated with purchased power, reveals a more complicated situation. Mill-level information available to NCASI suggests that the ranges in GHG emissions are significant among seemingly similar mills because they are heavily impacted by the selection of fuel. Indeed, the differences in greenhouse gas emissions between virgin and recycling mill manufacturing-related emissions can be outweighed by the effects of a selected fossil fuel within the mill's fuel mix.

In specific, NCASI's analysis reveals statistically significant differences between virgin mills and recycled mills (excluding emissions associated with purchased power) only in two cases:

1. for grades of board that compete with bleached kraft board (in which case recycled board mills tend to have lower emissions), and
2. newsprint mills (where recycling mills tend to have lower GHG emissions).

Manufacturing-Related GHG emissions

Mill emissions of GHGs are governed by the types and amounts of fuel burned, factors that can vary to a great degree among otherwise similar mills.

Because chemical pulp mills derive a large fraction of their energy from biomass fuels, primarily in the form of pulping liquors, studies often find that they have lower GHG emissions than recycling mills making comparable products. Statistical analysis of NCASI site-specific data, however, reveals no statistically significant differences in GHG emissions between virgin chemical pulp mills and recycled mills making comparable grades of board, paper, or tissue except for the bleached board sector, where the virgin mills tend to have higher GHG emissions than recycling mills making competing products.

The mills producing virgin mechanical pulp, used in products such as newsprint and phonebooks, do not generate pulping liquors and therefore have less access to biomass fuels. As a result, studies usually find that virgin mechanical pulp mills are more GHG-intensive than recycled mills making the same grades.

Data from a number of published studies are summarized in the following table. The emissions documented in the published literature include emissions from the mill and indirect emissions associated

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with purchased electricity. Although the table does not show data for tissue manufacturing, it would be expected that the comparison of energy requirements for virgin and recycled tissue manufacturing would be directionally similar to that for office paper since both involve bleached chemical pulp.

Table R8.

Product and Process Description	GHG Emissions from Manufacturing		Reference
Virgin newsprint	5478 lb/ton	2739 kg/tonne	Paper Task Force (2002)
Recycled newsprint	3269 lb/ton	1634.5 kg/tonne	
Virgin newsprint	2.10 tonne/ton	2315 kg/tonne**	USEPA (2012), includes raw material transportation
Recycled newsprint *	1.11 tonne/ton	1224 kg/tonne**	
Virgin corrugated boxes	2799 lb/ton	1399.5 kg/tonne	Paper Task Force (2002)
Recycled corrugated boxes	3240 lb/ton	1620 kg/tonne	
Virgin[1] corrugated containers	0.84 tonne/ton	926 kg/tonne**	USEPA (2012), includes raw material transportation
Recycled corrugated containers *	0.87 tonne/ton	959 kg/tonne**	
Virgin office paper	2995 lb/ton	1497.5 kg/tonne	Paper Task Force (2002)
Recycled office paper	3353 lb/ton	1676.5 kg/tonne	
Virgin office paper	1.01 tonne/ton	1114 kg/tonne**	USEPA (21012), includes raw material transportation
Recycled office paper *	0.81 tonne/ton	893 kg/tonne**	
Virgin coated unbleached board	2326 lb/ton	1163 kg/tonne	Paper Task Force (2002)
Virgin bleached board	2895 lb/ton	1447.5 kg/tonne	
Recycled Paperboard	3015 lb/ton	1507.5 kg/tonne	
Virgin magazines	1.67 tonne/ton	1841 kg/tonne**	USEPA (2012), includes raw material transportation
Recycled magazines *	1.11 tonne/ton	1224 kg/tonne**	
Virgin phonebooks	2.43 tonne/ton	2679 kg/tonne**	USEPA (2012), includes raw material transportation
Recycled phonebooks *	1.02 tonne/ton	1125 kg/tonne**	
Virgin textbooks	2.15 tonne/ton	2370 kg/tonne**	USEPA (2012), includes raw material transportation
Recycled textbooks *	1.37 tonne/ton	1510 kg/tonne**	

*Recycled product GHG emissions calculated from USEPA 2012 based on best interpretation of information therein.
**Converted from units of metric tonne per short ton.

[1] Note that USEPA 2012 considers "virgin" corrugated containers to be comprised of 9.8% recycled fiber.

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Other fossil fuel-related GHG emissions along the value chain

Other than emissions associated with purchased power, which are included in manufacturing emissions discussed elsewhere, the only GHG emissions that differ significantly between virgin and recycled value chains are those associated with fiber transportation.

Transportation distances related to fiber procurement and product delivery vary enormously. Wood, pulp, and recovered paper are now routinely shipped halfway around the globe. Therefore, to understand whether increased recycling causes significant increases in transportation-related GHG emissions, it is necessary to understand the relative distances and modes of transport involved in bringing additional recovered fiber to specific mills. If the transportation distances for virgin fiber and additional recovered fiber are greatly different, the impact of transportation-related GHG emissions can be significant to the overall GHG implications of increased recycling. Put another way, the assumption of “typical” transportation distances can yield misleading results in judging the effects of specific efforts to increase recycling.

One study that attempted to use typical transportation distances in the U.S. found that the GHG emissions associated with collecting and transporting virgin fiber (200 to 300 lb/ton) were not significantly different from the GHG emissions associated with collecting, processing and transporting wastepaper (about 220 lb/ton) (Paper Task Force 2002). These emissions are small compared to those for manufacturing (2300 to 5500 lb/ton) discussed elsewhere in this Tool.

It is important to repeat, however, that these “typical” results can mask site-specific circumstances where transportation-related GHG emissions might be much more significant. Those wanting to understand the GHG-implications of specific recycling initiatives will need information that allows them to judge the potential significance of transportation emissions. In specific, it will be necessary to know the likely distances and modes of transportation involved in bringing additional recovered fiber to mills.

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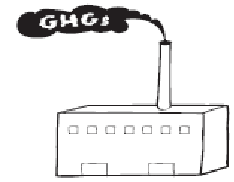

GREENHOUSE GASES

EFFECTS OF RECYCLED FIBER USE ON GREENHOUSE GAS EMISSIONS

Carbon Sequestered in Forests, Products and Landfills

Forest carbon sequestration

In most studies that examine the effects of recycling on GHG emissions, the effects of recycling on forest carbon sequestration are ignored. In those studies that attempt to estimate the impact of recycling on forest carbon, it is usually determined to result in additional sequestration. The estimated benefits of recycling to forest carbon sequestration, however, are highly uncertain because they depend on assumptions about, among other things, the effects of changes in virgin fiber demand on forest ownership and management decisions.

Some studies are based on the simple assumption that trees not needed for fiber will grow to maturity, sequestering carbon as they grow. In actuality, some of this sequestration benefit will be lost because, in the absence of a market for the fiber, some private forest owners will sell their land or convert it to other uses, usually resulting in reductions in carbon sequestration compared to a forest managed for fiber production. In addition, forests that are no longer managed will often be more susceptible to carbon loss due to fire or infestation. The magnitude of this loss, sometimes called “leakage,” is highly uncertain.

In one major U.S. study, the net benefits for paper recycling compared to landfilling were found to range from 2.65 to 3.11 tonnes CO_2 per short ton of paper recovered (USEPA 2012). Of this, 2.02 and 3.06 tonnes CO_2/ton (for mechanical pulp and chemical pulp, respectively) were due to anticipated increased forest carbon sequestration, meaning that forest carbon sequestration was largely responsible for the estimated benefits of recycling. In describing its study, USEPA pointed out limitations in the agency’s analysis.

- “The analysis… does not account for any potential long-term changes in land use caused by a reduction in pulpwood or softwood demand, and landowners’ choices to change land use from silviculture to other uses.”
- “Results are very sensitive to the assumption on paper exports (i.e., that paper exports comprise a constant proportion of total paper recovery).”
- EPA “applies a single point estimate reflecting a time period that best balances the competing criteria of (1) capturing the long-term forest carbon sequestration effects, and (2) limiting the uncertainty inherent in projections made well into the future. The variation in forest carbon storage estimates over time and the limitations of the analysis … indicate considerable uncertainty in the point estimate selected.”(USEPA 2012).

When considering the impacts of recycling on forest carbon, it is also important to understand that carbon stocks in U.S. and Canadian forests are not declining. This is due, in part, to the effectiveness of sustainable forest management practices. In the U.S., the carbon stored in forests is increasing at a rate of about 59 million metric tonnes of carbon per year (216 million metric tonnes CO_2 per year) (USEPA 2005). EPA estimated that the 2008 annual net carbon flux in U.S. forests was about 792 million metric tons of carbon dioxide equivalents, which offset about 3% of U.S. energy-related CO_2 emissions (USEPA 2012). Any increases in forest carbon sequestration attributable to increased recycling would occur on top of this already increasing pool of forest carbon.

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Product carbon sequestration

Carbon in paper and paperboard products is sequestered from the atmosphere. Over time, the amount of carbon sequestered in products is increasing, meaning that the amounts in the atmosphere are declining by a corresponding amount (Miner and Perez-Garcia 2007). The amount of carbon sequestered in products, however, does not depend on whether the product is made from virgin or recovered fiber. The effects of recycling on carbon sequestration occur in the forest and landfill.

Landfill carbon sequestration

In North America, large amounts of carbon are sequestered in paper and wood products discarded in landfills. Many assessments of paper recycling do not address carbon sequestration in products in use or in landfills, yet studies indicate that this sequestration represents a very important part of the value chain GHG profile of the industry, and is part of the overall accounting of the forest carbon cycle, as are the GHGs released during their degradation in these landfills (discussed elsewhere in this Tool).

If used forest products are recycled rather than landfilled, this reduces the amount of carbon sequestered in the landfill. In the long term, recycled fiber products will ultimately end up in landfills or burned, as paper or processing waste, but the quantities of fiber going to end of life will be smaller on an annual basis than would have been the case without recycling. (If forest products are recycled rather than an alternative of being burned for energy, there is no effect on carbon sequestration in landfills.) Thus, the assessment of recycling on carbon and greenhouse gas emissions must address the likely alternative fate of used products and if the alternative is landfilling, the assessment must account for the impacts on landfill carbon sequestration. It must also account for impacts on landfill methane releases, discussed elsewhere in this Tool.

For various grades of paper, USEPA has estimated the following impacts of landfilling on carbon sequestration (USEPA 2012).

Table R9

Product	Carbon Sequestered (metric tonnes of CO2 equivalents) per Wet Short Ton of Material Landfilled
Corrugated containers	0.82
Magazines/Third class mail	0.82
Newspaper	1.33
Office Paper	0.16
Phone Books	1.33
Textbooks	0.16

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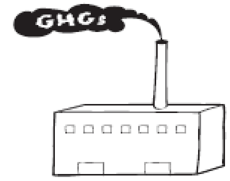
ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry



GREENHOUSE GASES

EFFECTS OF RECYCLED FIBER USE ON GREENHOUSE GAS EMISSIONS

Methane Emissions from Landfills

When used forest products are disposed of in landfills, they may decompose into carbon dioxide and methane. Because the decomposing forest products are biomass-based, the carbon dioxide is considered carbon neutral. Methane, however, is not considered carbon neutral because the carbon in methane is returned to the atmosphere in a much more potent form (i.e., in methane) than it was removed from the atmosphere (i.e., in carbon dioxide). On a pound for pound basis, methane is more than twenty times more potent than carbon dioxide in terms of its global warming potential. In cases where used forest products are landfilled, landfill GHG emissions are an important part of the value chain GHG profile. Some global estimates have found these emissions to be almost as important as the industry's GHG emissions from fossil fuel combustion (IIED 1996).

When paper is recycled instead of landfilled, methane emissions are avoided because, on an annual basis, less fiber goes to end of life than would have been the case had the fiber not been recycled. Estimating the avoided emissions, however, requires a great deal of information, much of which is site-specific and most of which is uncertain. Methane releases are primarily a function of (a) the type of paper or paperboard, (b) the design of the landfill as regards moisture and nutrient control, and (c) the efficiency of systems (if any) put in place to capture methane before it escapes to the atmosphere.

One of the most thorough North American studies of the effects of recycling on landfill emissions was a report titled *Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste*, first published by USEPA in 1998 and updated in 2002 and 2006. The current version exists as a series of documentation chapters to the agency's *Waste Reduction Model (WARM)*, available on the internet (USEPA 2012). The estimated impacts of landfilling on methane emissions for specific types of products, drawn from this documentation, are shown below (USEPA 2012).

Table R10.

Product	Methane generated* (metric tonnes of CO_2 equivalents) per Wet Short Ton of Material Landfilled	Methane Emitted (metric tonnes CO_2 equivalents) per Wet Short Ton of Material Landfilled**
Corrugated containers	2.52	0.82
Magazines/Third class mail	1.02	0.35
Newspaper	0.90	0.32
Office Paper	4.26	1.43
Phonebooks	0.90	0.32
Textbooks	4.26	1.43

*Quantities pertain to methane generation and do not reflect oxidation that naturally occurs near the surface nor in capture/destruction systems.

**Based on "typical" landfill gas collection practices and after assuming 10% of uncollected methane oxidizes naturally.

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Comparing these numbers with the landfill carbon sequestration numbers shown elsewhere in this Tool, one finds that the potential detrimental effect of methane emissions is larger than the potential positive effect of carbon sequestration in landfills for paper and paperboard products made from bleached chemical pulps (e.g., office paper and textbooks). Other grades contain sufficient lignin, which does not degrade in landfills and which also helps inhibit the degradation of the cellulose, to serve as a net sink of carbon. As a result, landfilling grades other than bleached chemical pulp can actually have a positive impact on atmospheric CO_2 levels (due to carbon sequestration in the landfill) when you consider only the emissions associated with end-of-life management. This is not a complete picture, however, since it ignores the many other implications of landfilling instead of recycling or burning for energy.

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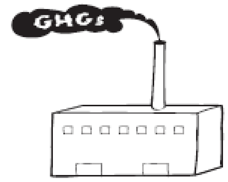

GREENHOUSE GASES

EFFECTS OF RECYCLED FIBER USE ON GREENHOUSE GAS EMISSIONS

Fossil Fuel-Related Emissions Avoided through Use of Paper-Derived Fuels

Used paper can be used as a fuel with significant heating value—10.5 to 15.9 MMBtu/short ton (USEPA 2012). This fuel value is one-half to three-quarters or more of that of coal. As a result, the effects of increased recycling on overall GHG emissions depend on whether the recovered paper would otherwise have been burned for energy and whether this is considered to have avoided use of fossil fuels.

In the studies examined by Finnveden and Ekvall (1998), 18 scenarios found lower fossil fuel use for systems where used paper packaging was burned for energy while eight found lower fossil fuel use in systems where used paper packaging was recycled. In comparing the studies, they found that the results depended primarily upon assumptions about what type of fuel was displaced by the paper-based fuel. Where paper-based fuel was assumed to displace fossil fuel, this was found to require less fossil fuel than a system involving paper recycling. Otherwise, the recycling system was found to have lower fossil fuel use. The researchers indicated that the same results would perhaps not hold for newsprint because of the large differences in energy intensity between virgin and recycled newsprint.

The Paper Task Force (2002) study assumed that paper-based fuel would displace fossil fuels. Except for the case of newsprint, the fossil fuel-related energy required for the system involving recycling was 6 to 9 MMBtu/ton of recovered paper greater than the system wherein used paper was burned for energy. In the case of newsprint, recycling and burning for energy required approximately the same amount of fossil fuel.

The results of the USEPA (2012) comparison of burning and recycling to landfilling is shown in the following table. USEPA's analysis shows greater benefits for recycling compared to burning for energy across all grades. This is primarily because USEPA's analysis includes large estimated forest carbon benefits for recycling whereas other studies do not. These benefits, however, are admitted to be very uncertain.

Table R11

Product	Net GHG Emissions from a Landfilling System (metric tonnes of CO_2 equivalents per wet short ton of material)*	GHG Emissions from a Recycling-Based System (metric tonnes of CO_2 equivalents per wet short ton of material)	GHG Emissions from a Burning for Energy-Based System (metric tonnes of CO_2 equivalents per wet short ton of material)**
Corrugated containers	-0.05	-3.11	-0.48
Magazines/Third class mail	-0.47	-3.07	-0.35
Newspaper	-1.01	-2.78	-0.55
Office paper	1.17	-2.85	-0.47

(Continued on next page. See notes at end of table.)

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Table R11 (Continued)

Product	Net GHG Emissions from a Landfilling System (metric tonnes of CO_2 equivalents per wet short ton of material)*	GHG Emissions from a Recycling-Based System (metric tonnes of CO_2 equivalents per wet short ton of material)	GHG Emissions from a Burning for Energy-Based System (metric tonnes of CO_2 equivalents per wet short ton of material)**
Phone books	-1.01	-2.65	-0.55
Textbooks	1.17	-3.11	-0.47

*Includes consideration of oxidation of generated CH_4, offset of utility generated power, and carbon stored in landfills
**Biogenic CO_2 from combustion is not included

In summary, burning used paper as a substitute for fossil fuels reduces total (life cycle) GHG emissions compared to landfilling for corrugated containers, office paper, and textbooks, whereas landfilling has a greater GHG benefit for magazines/third class mail, newspaper, and phone books (USEPA 2012). Most studies suggest that the GHG benefits from recycling newsprint are greater than those from burning newsprint for energy, but the results for other grades of paper and paperboard vary depending on the boundaries of the study and other assumptions, especially those regarding carbon storage in forests attributed to increased recycling.

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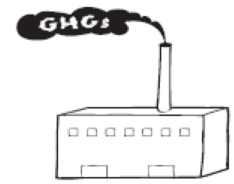

GREENHOUSE GASES

EFFECTS OF RECYCLED FIBER USE ON GREENHOUSE GAS EMISSIONS

Overview of Two Significant Studies of the U.S. Situation

In the documentation for the USEPA's Waste Reduction Model (WARM), the agency reports the detailed results of a life cycle study focused on the greenhouse gas and carbon implication of different methods for managing solid waste (USEPA 2012). For paper and paperboard products, USEPA examines the life cycle effects of source reduction, recycling, burning for energy, and landfilling. This is one of the few studies that attempts to address the entire life cycle, including effects on forest carbon. It provides detailed information on the various elements of the study, allowing the user to understand the relative importance of, for instance, avoided methane emissions compared to manufacturing emissions. The data in the USEPA report can be applied to specific analyses using USEPA's online tool, the WARM.

The attempt to include forest carbon in the analysis has advantages and drawbacks. The primary advantage is that it helps the user understand the connection between forest carbon and downstream processes and markets. The major disadvantage is that, as the report explains, there is "considerable uncertainty" in the estimates of impacts on forest carbon. Unfortunately, as explained in the chapter "Forest Carbon Storage," the forest carbon impacts overwhelm the quantitative results of the analysis. The greenhouse gas benefits of recycling are largely or entirely driven by the estimates of increased forest carbon sequestration.

The modeling framework used in the USEPA study does not address the deforestation that might result from depressed prices for pulpwood due to increased recycling. The likelihood and importance of this possibility are frequently debated and are likely dependent on number of factors, including the type of wood and the region involved. In a study of the factors influencing land use change in the southeastern U.S., Hardie and Parks (1997) found that "the region's land base is not greatly affected by marginal changes in farm and forest net revenues or by small differences in land quality across counties," a finding that suggests that recycling may not result in significant leakage due to land use change in the Southeast U.S. This study also suggests that leakage is less affected by the pulpwood market than by the saw timber market. Until leakage effects are studied in more situations, however, it is not possible to know the extent to which USEPA's approach to modeling forest carbon might overstate the sequestration benefits of recycling.

Other limitations of the study are that (a) it does not include carbon sequestered in forest products during use and (b) does not consider the time-dependent fate of carbon in landfills over time. The significance of these limitations to the results of USEPA's analysis, however, is uncertain.

In spite of the limitations, the USEPA report contains perhaps the best documented study of the trade-offs involved in recycling and greenhouse gas emissions. The overall results are shown in the following table. The table also illustrates the importance of forest carbon sequestration estimates, which are acknowledged by USEPA to be subject to "considerable uncertainty."

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Table R12.

Product	Net GHG Emissions, from a Waste Generation Reference Point Metric Tonnes CO_2 Equivalents per Wet Short Ton of Material			
	Recycling		Combustion with Energy Recovery (mass burn facilities)	Landfilling
	With Forest Carbon Sequestration	Without Forest Carbon Sequestration*		
Corrugated containers	-3.11	-0.05	-0.48	-0.05
Magazines/Third class mail	-3.07	-0.01	-0.35	-0.47
Newspaper	-2.78	-0.76	-0.55	-1.01
Office paper	-2.85	0.21	-0.47	1.17
Phone books	-2.65	-0.63	-0.55	-1.01
Textbooks	-3.11	-0.05	-0.47	1.17

*Calculated from results in USEPA 2012.

Another widely cited study is that by the Paper Task Force (2002). For several reasons, many of the results from that study, including the overall results, are not included here. First, the methods used in the report did not address carbon sequestration in forests or products which, as discussed above, are important parts of the industry's GHG profile and are required to provide full forest carbon accounting. In addition, the methods used in the Paper Task Force report to estimate paper-related methane emissions from landfills are not consistent with methods that have since been developed for estimating these emissions under a variety of GHG reporting guidelines. For some grades of paper examined in the Paper Task Force report, these emissions represented more than one-half of the life cycle GHG emissions, indicating that the limitations of the estimation methods could have a large effect on the overall results.

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CHLORINATED COMPOUNDS

EFFECTS OF RECYCLED FIBER USE ON CHLORINATED COMPOUNDS

Overview

The effects of paper recycling on the use or discharge of chlorine-containing compounds occur primarily in bleaching.

Several substances once associated with bleaching (e.g., dioxin and highly chlorinated phenolic compounds) are now below levels that can be detected in effluents at both virgin and recycling mills. Chloroform is generated in small amounts at virgin mills that use chlorine dioxide for bleaching and in larger and comparable amounts at virgin and recycling mills using sodium hypochlorite for bleaching or brightening. Polychlorinated biphenyls (PCBs), which in the past entered recycling mills in certain carbonless copy papers, are now seldom detected in mill effluents.

Total quantities of chlorinated organic compounds in effluents, measured as adsorbable organic halides (AOX), will often tend to be higher in virgin mill effluents because greater quantities of chemicals are required to bleach virgin pulp compared to the amounts applied to recovered fibers. Studies of the significance of the chemicals measured in the AOX test, however, suggest that they are not of particular environmental concern.

In cases where all chlorine-containing chemicals used for bleaching in virgin or recycling mills are eliminated (i.e., totally chlorine free (TCF) or process chlorine free (PCF) mills), the potential for generating chlorinated organic chemicals is also eliminated, but small amounts of chlorinated organic chemicals may continue to enter the mill as contaminants in recovered fiber or other raw materials.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Pulp bleaching and brightening

PCBs in recovered fiber

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CHLORINATED COMPOUNDS

EFFECTS OF RECYCLED FIBER USE ON CHLORINATED COMPOUNDS

Pulp Bleaching and Brightening

Until the 1990s, most chemical pulp mills used chlorine and chlorine dioxide to bleach pulp and some mills also used sodium hypochlorite. The discovery, in the mid-1980s, that dioxin can be formed when chlorine is used to bleach chemical pulps led to changes in the chemicals used for pulp bleaching. The most notable change was the elimination of chlorine and hypochlorite in favor of chlorine dioxide in the sequence referred to as “elemental chlorine free” (ECF) bleaching. This conversion also led to the increased use of oxygen and hydrogen peroxide in the pulping and/or bleaching sequence. Complete elimination of all chlorine compounds in pulp bleaching in favor of oxygen, peroxide and other non-chlorine containing chemicals is termed “totally chlorine free” (TCF) bleaching.

The characteristics of wastewater from a bleached chemical pulp mill are highly influenced by bleaching operations. This is because a large portion of the wastewater produced at a mill originates from bleaching operations given that its chemical characteristics do not allow it to be recycled in a straightforward manner, compared to effluents from other areas of the mill. Compounds that derive from bleaching operations, the generation of which is known to be affected by the use of the various bleaching chemicals, include dioxin and furan (2,3,7,8-TCDD and 2,3,7,8-TCDF), substituted chlorinated phenolic compounds, chloroform, and adsorbable organic halides (AOX; a measure of total chlorinated organic material).

2,3,7,8-TCDD and 2,3,7,8-TCDF

In the 1980s, 2,3,7,8-TCDD and 2,3,7,8-TCDF (sometimes called “dioxin” and “furan”, respectively) were found to be unintended byproducts when chlorine was used for virgin chemical pulp bleaching. Extensive measurement of effluents from ECF bleach plants shows that measurable levels of 2,3,7,8-TCDD are not found and that 2,3,7,8-TCDF is only very rarely found at quantifiable levels (USEPA 2006). In virgin chemical pulp bleaching, TCF bleaching eliminates any possibility that these compounds might be formed, even at levels below analytical detection limits.

Recycled mills do not use chlorine for bleaching but some recycling mills that produce tissue or fine paper use sodium hypochlorite for brightening of pulp. Hypochlorite is not used in brightening newsprint. The chemistry of formation of 2,3,7,8-TCDD and 2,3,7,8-TCDF in kraft pulp bleaching, described in NCASI Technical Bulletin No. 819 (NCASI 2001) provides little reason to expect that these compounds are formed in hypochlorite bleaching at virgin or recycled mills. Measurements of treated effluents from recycled mills for dioxins and furans (NCASI 1994) in the 1990s showed 2,3,7,8-TCDD to be below analytical minimum levels in all cases and 2,3,7,8-TCDF to occur only very rarely – likely due to the presence of the compound in the recovered paper supply rather than pulp brightening.

Chlorinated Phenolic Compounds

A number of chlorinated phenolic compounds are of concern because of their toxicity and resistance to biological treatment. Of particular concern are the highly substituted phenolics, i.e., the tri-, tetra-, and penta-substituted phenols, catechols, and guaiacols. Of these, 13 compounds are predominant, and some were shown to be generated during the chlorine bleaching of chemical pulps. Extensive measurement of effluents from ECF bleach plants shows that these compounds are only very rarely detected at quantifiable levels (USEPA 2006). TCF bleaching eliminates any possibility that these compounds might be formed, even at levels below analytical detection limits.

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While as noted above, some recycling mills use sodium hypochlorite for brightening of pulp, the chemistry of formation of highly substituted phenolics in kraft pulp bleaching, described in NCASI Technical Bulletin No. 819 (NCASI 2001), provides little reason to expect that chlorinated phenolic compounds are formed in hypochlorite bleaching in virgin or recycled mills.

Chloroform

Chloroform is a by-product of bleaching with sodium hypochlorite, chlorine, and, to a much lesser extent, chlorine dioxide. Chloroform is not known to be produced by oxygen, peroxide, or other non-chlorinated bleaching chemicals. Figure R6 shows the magnitude of chloroform generation associated with a typical virgin pulp bleach line using chlorine and hypochlorite and a typical line using only chlorine dioxide (ECF). Chloroform loads from TCF mills would be zero.

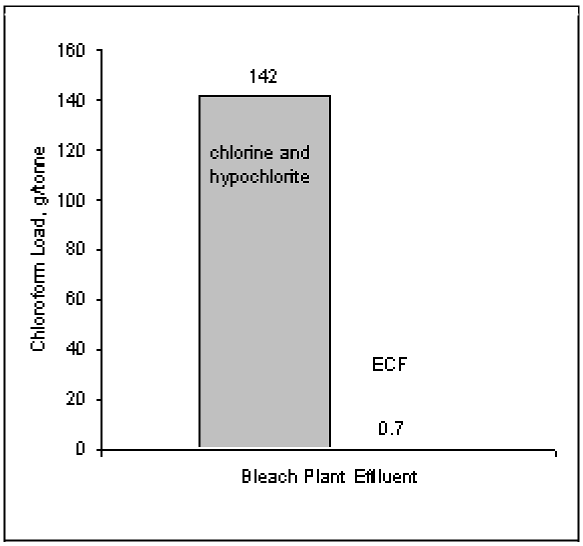

Figure R6.
Chloroform Load from Chlorine+Hypochlorite and
Chlorine Dioxide (ECF) Bleaching of Kraft Pulp (USEPA 1997)

As is apparent in the figure, 99.5% of the reduction in chloroform is achieved through implementation of ECF bleaching. The remaining 0.5% reduction could be achieved through TCF bleaching.

Chloroform is also produced as a by-product of brightening recovered fiber with sodium hypochlorite. The generation of chloroform in recovered fiber brightening stages using hypochlorite is similar in magnitude to that associated with hypochlorite bleaching of virgin pulps, ranging between about 0.12 and 1.2 kg/air dry metric ton (ADMT) of pulp (Dence and Reeve 1996). A portion of this chloroform would be emitted in bleach plant vents and the remainder with bleach plant wastewater sent for treatment. Elimination of hypochlorite from the brightening system in favor of peroxide or other non-chlorine containing brightening agents would eliminate most or all generation of chloroform.

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AOX

AOX is a non-specific measurement parameter representing the amount of chlorinated organic material present in wastewater. It is often used as a general indicator of the amount of chlorine and chlorine-compounds used in virgin pulp bleaching. It is seldom measured at recycling mills, however.

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ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry

CHLORINATED COMPOUNDS

EFFECTS OF RECYCLED FIBER USE ON CHLORINATED COMPOUNDS

PCBs in Recovered Fiber

Polychlorinated biphenyls (PCBs) can sometimes enter the recovered paper stream in the form of old carbonless copy paper (produced before 1971, when the use of PCBs in such products was stopped). In years past, as these papers were recovered for recycling they tended to be found primarily in grades of recovered paper used by deinking mills. By now, almost all of the old paper that contained PCBs has been purged from files so that likelihood of finding PCBs in mills wastes due to recycling of old carbonless copy paper has declined dramatically. Because this has been an issue of diminishing importance, there has been little effort to collect recent monitoring data, but a study by NCASI in the early 1990s found that levels of PCBs in post-1989 effluent samples from 11 deinking mills effluents were below detectable levels 99% of the time (NCASI 1994).

Reference

National Council [of the Paper Industry] for Air and Stream Improvement, Inc. (NCASI). 1994. *PCB and TCDD/F levels in effluents from deinking mills producing fine paper or tissue and toweling*. Technical Bulletin No. 671. New York: National Council of the Paper Industry for Air and Stream Improvement, Inc.

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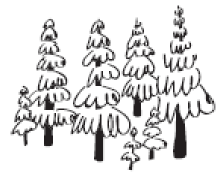

WOOD USE

EFFECTS OF RECYCLED FIBER USE ON LAND AND WOOD USE

Overview

Recycling reduces demand for virgin wood fiber. The size of the impact is difficult to estimate and will vary by region and product type.

It will always be necessary, however, to harvest trees to provide new (virgin) fiber to the fiber supply. New fibers find their way into the recycled paper stream, improving the quality of recycled fiber. In addition, it is impossible to recycle 100% of the paper that is used so a certain amount of virgin fiber will always be required.

Reduced demand for virgin fiber does not translate directly into reduced pressures on forests. In the case of private forest land, the harvesting of trees to meet demand for forest products provides income to landowners that helps reduce the incentives to convert forestland to other uses. Pressures to convert forests to non-forest uses may increase if the market for wood fiber declines Therefore, if one is concerned about keeping land in forest rather than wood use *per se*, activities that reduce the demand for virgin fiber can actually cause detrimental effects.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Demand for virgin wood fiber

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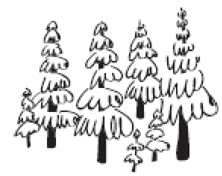

WOOD USE

EFFECTS OF RECYCLED FIBER USE ON LAND AND WOOD USE

Demand for Virgin Wood Fiber

By providing an alternative source of fiber, paper recovery can reduce the demand for virgin wood fiber. There are limits, however, on how much recovered fiber can displace virgin fiber. First, virgin and recovered fibers sometimes have different properties making them more or less suitable for use in specific applications. Second, there are limits to how much fiber can be economically or practically recovered. Third, there is a need for new fiber to enter the system to offset losses that occur at many points along the fiber value chain (Metafore 2006).

Developing quantitative estimates of impacts on forests when recycling is increased (i.e., how many trees are “saved”) is complicated and uncertain because the estimates depend on assumptions about the effects of changes in virgin fiber demand on forest ownership and management decisions. For instance, lacking a market for pulpwood, some private forest owners may sell their land for development while other forest owners may choose to allow the trees to grow until they are suitable for use as saw timber, delaying but not eliminating the harvest.

In addition, the effect of recycling on wood demand varies among different types of products because of differences in yields (i.e., the amount of final product obtained from the raw material). For instance, all else being equal, recycling newsprint will have less of an effect on harvesting than recycling containerboard because a greater fraction of the tree is incorporated into newsprint compared to containerboard.

Some studies are based on the simple assumption that trees not needed for fiber will remain in the forest and never be harvested. In actuality, some of this forestland will be lost because, in the absence of a market for pulpwood, some forest owners will sell their land or convert it to other uses, often resulting in the removal of some or all of the tree cover. The significance of this loss, sometimes called “leakage”, is debated but is likely dependent on number of factors, including the type of wood and the region involved. In a study of the factors influencing land use change in the southeastern U.S., Hardie and Parks (1997) found that “the region's land base is not greatly affected by marginal changes in farm and forest net revenues or by small differences in land quality across counties,” a finding that suggests that recycling may not result in significant leakage due to land use change in the Southeast U.S.. This study also suggests that leakage is less affected by the pulpwood market than by the saw timber market. Until leakage effects are studied in more situations, however, it is not possible to know the extent to recycling impacts forests.

When considering the impacts of recycling on forests, it is also important to understand that the area of U.S. and Canadian forests is not declining. Forested area is larger now than in the 1800s and has been stable at about 750 million acres since the 1950s. To the extent that forest land may be threatened in the future, it is not the use of wood for paper and wood products that represents the threat. The U.S. Forest Service predicts that “reduction in forest land will mainly result from conversion to other land uses such as reservoirs, urban expansion, highway and airport construction and surface mining” (Haynes 2003.

Thus, while recycling will reduce demand for pulpwood, it is not accurate to assume that reduced harvesting for forest products will help maintain forests. Indeed, the opposite driving force is in play, at least for privately-owned forest land—the markets for forest products help keep land in forest, reducing the chances that it will be converted to non-forest uses.

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EFFECTS OF RECYCLED FIBER USE ON ODOR

Overview

Objectionable odors can arise from a number of sources. Reduced sulfur odors, causing a “rotten egg” smell, have been associated with emissions from kraft mills, although recent control requirements have greatly reduced these odors. At an increasing number of kraft mills, process-related odors are noticed in communities only during intermittent process upsets. Reduced sulfur compounds as well as other types of compounds (e.g., certain organic acids) can also create odors that are noticed in the vicinity of virgin and recycled paper mill waste treatment facilities.

Recycled paper mills do not have the reduced sulfur process-related odors that are associated with kraft mills, but other common sources of community odor are not related to whether a mill is a recycled or virgin mill. Odors can arise from sludge dewatering areas (hydrogen sulfide and volatile organic acids) as well as the wastewater treatment area. If sulfate is present in the wastewater, it can be converted to hydrogen sulfide by sulfate-reducing bacteria, especially if anaerobic conditions are present during wastewater treatment. Hydrosulfite, which is commonly used to bleach recycled fiber, can provide a source of sulfate in the wastewater. These issues are often avoided by maintaining an oxidative environment in the wastewater treatment system.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry’s fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

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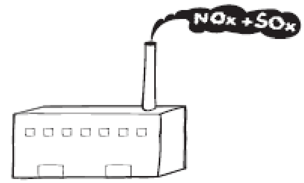
ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry



EMISSIONS TO AIR

EFFECTS OF RECYCLED FIBER USE ON EMISSIONS TO AIR

Overview

Increased recycling can affect combustion-related emissions and emissions associated with mill processes, but the effects are very different and must be considered separately.

Fuel combustion-related emissions of particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds (VOCs) are not well correlated with whether the mill is a virgin mill or a recycling mill. (Greenhouse gas emissions are addressed elsewhere in this Tool.)

The amounts of combustion-related emissions are related primarily to the type of fuel, the amounts burned, the type of combustion device, and the emission control devices being used. Because virgin mills often burn more fuels on-site, fuel combustion-related emissions are often higher from virgin mills than recycling mills making comparable grades.

There are also fuel combustion-related emissions, however, from off-site suppliers of electricity. When the emissions associated with purchased electricity are included, the differences between virgin and recycled mills essentially disappear (except perhaps for newsprint).

Other emissions, primarily from mill processes, can differ between virgin and recycled production. However, because the different substances emitted are not of equal environmental or human health significance, it is not possible to say whether there are overall benefits to air emissions associated with increased recycling. The differences in the emissions of particular substances, however, are sometimes significant.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Fuel combustion-related emissions

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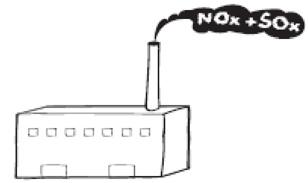

EMISSIONS TO AIR

EFFECTS OF RECYCLED FIBER USE ON EMISSIONS TO AIR

Fuel Combustion-Related Emissions

Sulfur dioxide (SO_2)

Emissions of sulfur dioxide (SO_2) from fossil fuel combustion at a pulp and paper mill depend primarily on the sulfur content of the fuel and whether control devices are used to scrub combustion gases. Natural gas normally has very little sulfur, while the sulfur levels in oil and coal are highly variable and can be quite high (USEPA 1995). Because of the importance of fuel sulfur content, the differences between recycling and virgin fiber mills are difficult to discern.

For several biomass fuels important to virgin pulp mills, wood waste and black liquor in particular, the sulfur in the fuel is largely captured during combustion so that the SO_2 emissions from black liquor combustion and burning bark and wood waste are very small compared to those from burning fossil fuels (NCASI 2004).

The Paper Task Force examined life cycle emissions of SO_2 from virgin and recycled manufacturing (Paper Task Force 2002). The results reveal no large or consistent differences between virgin and recycled production, with the possible exception of newsprint. We assume that the higher emissions for virgin newsprint in the Paper Task Force study are not due to mill emissions but rather reflect the SO_2 associated with the large amounts of purchased power required for virgin newsprint production. (In the U.S., about one-half of the electrical power is from coal, although this varies significantly from one region of the U.S. to another. Note that in areas where electrical power is largely hydro power, this would significantly reduce estimated purchased power emissions.) This assumption is confirmed by statistical analysis of NCASI data on mill emissions (i.e., not including effects of purchased power), which failed to demonstrate a significant difference in mill SO_2 emissions between virgin and recycled newsprint mills.

The Paper Task Force results are generally consistent with a conclusion that mill-level and life cycle SO_2 emissions largely depend on factors other than whether a mill is virgin or recycled. Nonetheless, statistical analysis of NCASI site-specific data, which do not address purchased power, suggests that in the paperboard sectors, virgin mills tend have higher emissions of SO_2 than comparable recycling mills, presumably due to the selection of fuels.

Nitrogen Oxides (NOx)

Nitrogen oxides are produced during combustion from nitrogen in fuel and from atmospheric nitrogen. The amounts formed from atmospheric nitrogen vary by fuel type and can be controlled by combustion conditions, a phenomenon that is put to work in a variety of NOx control technologies. NOx emissions, therefore, depend on fuel nitrogen content, fuel type, combustion conditions, and the use of NOx controls. In addition, they depend on the amounts of fuel burned. These mill-specific factors, in particular fuel type, combustion conditions, and NOx controls, greatly complicate comparisons between industry sub-sectors.

The Paper Task Force report (2002) does not reveal large lifecycle differences in NOx emissions between virgin and recycled production, except perhaps for newsprint. In the case of newsprint, again, it can be assumed that the differences may not be due to on-site mill emissions but rather due to NOx associated with purchased power at virgin newsprint mills. These emissions will vary according to the source of the purchased electrical power.

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Statistical analysis of NCASI site-specific data suggests that NOx emissions from virgin mills are higher than those from recycling mills producing board, tissue, and fine papers. These findings probably reflect the types and amounts of fuels being used. No significant difference is evident in NCASI site-specific data, between mill-site NOx emissions from virgin and recycled newsprint mills.

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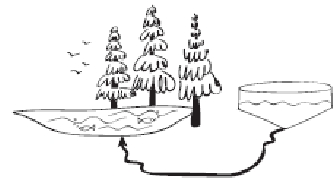
DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Overview

In general, mills producing recycled paperboard, containerboard, tissue, and fine paper discharge less biochemical oxygen demand (BOD) and total suspended solids (TSS) than virgin mills making comparable products. The differences between virgin and recycled newsprint mills, however, are not significant.

With few exceptions, the wastewaters from mills in North America are treated before being discharged. This diminishes differences in BOD and TSS loads between mill types. COD (chemical oxygen demand) is less treatable than BOD and as a result, the differences between production categories tend to be larger for COD than for BOD.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Paperboard

Containerboard

Recycled Paperboard

Newsprint

Tissue

Fine paper

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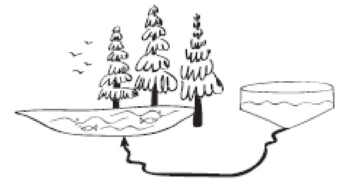

DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Paperboard Sector

There are many types of paperboard, but the main division is between containerboard and recycled paperboard. Both containerboard and recycled paperboard contain large amounts of recycled fiber.

Containerboard is used in corrugated boxes. The outside layers of the corrugated material are made of a fiber sheet called linerboard or test liner and the middle fluted layer is called corrugating medium, medium, or fluting. Therefore, containerboard is often divided into two groups, liner and medium. Within the containerboard sector, product specifications vary and these specifications may affect the use of recovered fiber as well as mill waste loads.

BOD and TSS discharges from containerboard mills with virgin pulping on site are usually greater than at mills using only recovered fiber, although NCASI data indicate that effluent loads from semi-chemical medium mills are much closer to recycled containerboard mills than are the loads from unbleached kraft linerboard mills. For more detailed information on containerboard mills, click here.

The opportunities to increase the use of recovered fiber in recycled paperboard manufacture are very grade-dependent. In some cases, the product niches filled by recycled paperboard are supplied only by mills producing board from 100% recovered fiber, so there are no opportunities to consider. In some cases, recycled paperboard and solid bleached sulfate (paperboard made from virgin bleached kraft pulp) compete in the same product niche. In other cases, recycled paperboard may compete against unbleached kraft board grades. The specificity of many of these product niches complicates comparisons of environmental parameters. None-the-less, recycled paperboard mills usually discharge less BOD, TSS and COD (chemical oxygen demand) than bleached and unbleached kraft mills. For more specific information on some of the recycled fiber-related environmental footprint decisions involving recycled paperboard mills, click here.

Additional information on the fiber quality requirements for paperboard manufacturing can be found in Gottsching and Pakarinen (2000).

More information on the sources of fiber in containerboard and recycled paperboard mills in the U.S. is available at http://paperrecycles.org/statistics. Comparable information from other countries is usually available from the country's paper industry trade association.

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Gottsching, L. and H. Pakarinen. 2000. *Recycled fiber and deinking*. Book 7 in Papermaking Science and Technology Series, ed. J. Gullichsen and H. Paulapuro. Helsinki, Finland: Finnish Paper Engineers' Association and TAPPI.

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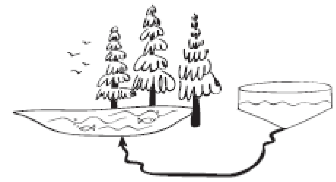

DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Containerboard Sector

Mills with virgin pulp production vs. 100% recycled containerboard mills: This section explains that, in general, mills producing containerboard from only recovered fiber have effluent biochemical oxygen demand (BOD) and total suspended solids (TSS) that are lower than mills that have virgin pulp mills on site. This finding is generally supported by statistical analysis of NCASI data, although NCASI data indicate that the differences between recycled containerboard mills and semi-chemical medium mills are smaller than those between recycled containerboard mills and unbleached kraft linerboard mills.

Effluent BOD, TSS, and especially COD (chemical oxygen demand) in treated effluents from containerboard mills with virgin pulping, especially kraft pulping, are usually higher than those from mills using only recovered fiber. Some of the published values for representative effluent loads from virgin and recycled containerboard production are shown in the following table.

Table R13.

Mill Description	Effluent BOD (kg/tonne)	Effluent COD (kg/tonne)	Effluent TSS (kg/tonne)	Reference
Unbleached kraft pulp mills using Best Available Techniques	0.2 to 0.7	5 to 10	0.3 to 1.0	EC BREF 2001
Recycled board mills using Best Available Techniques	<0.05 to 0.15	0.5 to 1.5	0.05 to 0.15	
Typical virgin containerboard mills (weighted average of linerboard and medium mills)	1.95	21.6	3.05	Paper Task Force 2002
Typical recycled containerboard mill	1.8	1.0	0.85	

References

European Commission BAT Reference (BREF). 2001. *Integrated Pollution Prevention and Control (IPPC) reference document on best available techniques in the pulp and paper industry.* Seville, Spain: European Commission Joint Research Centre. http://eippcb.jrc.es/reference/pp.html

Paper Task Force. 2002. *Paper Task Force recommendations for purchasing and using environmentally preferable paper.* http://epa.gov/epawaste/conserve/tools/warm/pdfs/EnvironmentalDefenseFund.pdf

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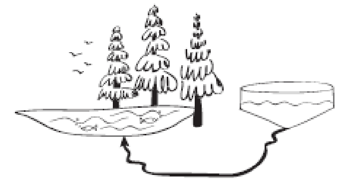

DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Recycled Paperboard Sector

In many segments of the recycled paperboard sector, mills use little, if any, virgin fiber. Recycled fiber-related environmental footprint decisions exist, therefore, only in a few categories where the same general product type can be made using significant amounts of virgin fiber.

In general, mills producing paperboard only from recycled fiber discharge less biochemical oxygen demand (BOD) and total suspended solids (TSS), and especially COD (chemical oxygen demand) than those making competing products from virgin fiber (assuming that the virgin fiber is produced on site). This finding is confirmed by statistical analysis of NCASI site-specific BOD and TSS data.

The following table summarizes published data on the effluent BOD, TSS, and COD discharges from recycled paperboard mills, unbleached kraft (sulfate) mills, and bleached kraft (sulfate) mills. The information makes it clear that while there is significant variability, mills producing recycled paperboard tend to have lower effluent loads than those producing paperboard from virgin pulp.

Table R14.

Mill Description	Effluent BOD (kg/tonne)	Effluent COD (kg/tonne)	Effluent TSS (kg/tonne)	Reference
Unbleached kraft pulp mills using Best Available Techniques	0.2 to 0.7	5 to 10	0.3 to 1.0	EC BREF 2001
Recycled board mills using Best Available Techniques	<0.05 to 0.15	0.5 to 1.5	0.05 to 0.15	
Typical virgin unbleached kraft mills making coated unbleached paperboard	1.7	18.5	2.75	Paper Task Force 2002
Typical virgin bleached kraft mills making solid bleached sulfate paperboard	3.45	50	5.55	
Typical recycled paperboard mill	1.05	1.0	0.85	

References

European Commission BAT Reference (BREF). 2001. *Integrated Pollution Prevention and Control (IPPC) reference document on best available techniques in the pulp and paper industry.* Seville, Spain: European Commission Joint Research Centre. http://eippcb.jrc.es/reference/pp.html

Paper Task Force. 2002. *Paper Task Force recommendations for purchasing and using environmentally preferable paper.* http://epa.gov/epawaste/conserve/tools/warm/pdfs/EnvironmentalDefenseFund.pdf

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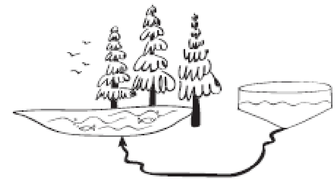

DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Newsprint Sector

A large and growing number of grades of printing and writing paper are made primarily from mechanical pulp. These are explained in Paulapuro (2000). Almost all of the recovered old newspapers used for papermaking, however, are used to produce newsprint. Therefore, this section focuses on the co-benefits and trade-offs when recycled newsprint is used in place of virgin mechanical pulp. The information below may apply to other grades of paper made from mechanical pulp, but this should not be assumed true unless confirmed by more grade-specific information.

Many mills now have facilities for producing both virgin mechanical pulp and recycled pulp from old newspaper (ONP). Therefore, in many situations, the effects of increasing recycled content will require examination of how the increase affects specific mills.

In any event, as the published information in the table below illustrates, there is significant overlap in the range of effluent loads of BOD, TSS and COD (chemical oxygen demand) for virgin mechanical newsprint and recycled newsprint mills. Therefore, in general, one would not expect that increasing recycled content of newsprint would have a significant effect on these parameters. This is confirmed by statistical analysis of NCASI site-specific data on BOD and TSS in final effluents.

Table R15.

Mill Description	Effluent BOD (kg/tonne)	Effluent COD (kg/tonne)	Effluent TSS (kg/tonne)	Reference
Mechanical pulp mills using Best Available Techniques and using at least 50% mechanical pulp	0.2 to 0.5	2.0 to 5.0	0.2 to 0.5	EC BREF 2001
Deinking mill using Best Available Techniques	<0.05 to 0.2	2.0 to 4.0	0.1 to 0.3	
Typical virgin newsprint mill	1.5	21.65	2.9	Paper Task Force 2002
Typical recycled newsprint mill	3.05	13.8	3.45	

References

European Commission BAT Reference (BREF). 2001. *Integrated Pollution Prevention and Control (IPPC) reference document on best available techniques in the pulp and paper industry.* Seville, Spain: European Commission Joint Research Centre. http://eippcb.jrc.es/reference/pp.html

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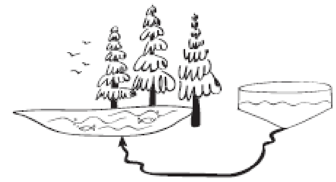

DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Tissue Sector

Where tissue is manufactured at mills with virgin pulping, the most common virgin pulps produced are bleached kraft (sulfate) and bleached sulfite, although a few bleached sulfite mills remain. Therefore, the co-benefits and trade-offs examined in this section compare recycled tissue manufacturing with tissue manufactured from virgin bleached kraft pulp.

There is very little literature comparing recycled to virgin tissue production. The recommendations issued by the European Commission are shown in the following table. The EC analysis suggests that BOD, COD (chemical oxygen demand), and TSS in treated effluents from deinked tissue mills will tend to be lower than those from bleach kraft mills manufacturing tissue. This is confirmed by statistical analysis of NCASI site-specific data.

Table R16.

Mill Description	Effluent BOD (kg/tonne)	Effluent COD (kg/tonne)	Effluent TSS (kg/tonne)	Reference
Bleached kraft (sulfate) pulp mills using Best Available Techniques	0.3 to 1.5	8 to 23	0.6 to 1.5	EC BREF 2001
Deinked tissue mill using Best Available Techniques	<0.05 to 0.5	2.0 to 4.0	0.1 to 0.4	

References

European Commission BAT Reference (BREF). 2001. *Integrated Pollution Prevention and Control (IPPC) reference document on best available techniques in the pulp and paper industry.* Seville, Spain: European Commission Joint Research Centre. http://eippcb.jrc.es/reference/pp.html

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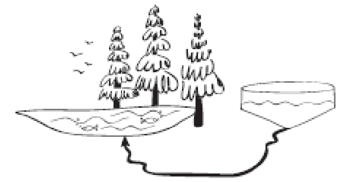

DISCHARGES TO WATER

EFFECTS OF RECYCLED FIBER USE ON DISCHARGES TO WATER

Fine Paper Sector

The fine paper sector includes a large number of product types. The product most commonly examined for environmental footprint decisions with respect to recycling is office paper (also known as copy paper or, in the industry's terminology, uncoated free sheet). This section, therefore, focuses on uncoated free sheet/copy paper. A discussion of the effects of recycled fiber on paper properties is beyond the scope of this Tool. The reader should consult with manufacturers to better understand the constraints on fiber furnish that may be associated with the manufacture of products with specific properties.

Where fine paper is manufactured at mills with virgin pulping, the most common virgin pulp produced is bleached kraft (sulfate). Therefore, the co-benefits and trade-offs examined in this section compare recycled copy paper manufacturing with copy paper manufactured from virgin bleached kraft pulp.

A number of mills can produce both virgin pulp and recycled pulp for use in copy paper. Therefore, in many situations, the effects of increasing recycled content will require examination of how it affects specific mills. The available literature does not provide clear indications as to whether BOD and TSS loads from recycled fine paper mills are different from virgin fine paper mills, although COD (chemical oxygen demand) loads are lower in recycled mill effluents. Statistical analysis of NCASI site-specific data suggests that BOD and TSS loads in treated effluents will tend to be lower in recycled fine paper mills than those from virgin fine paper mills.

Table R17.

Mill Description	Effluent BOD (kg/tonne)	Effluent COD(kg/tonne)	Effluent TSS (kg/tonne)	Reference
Bleached kraft (sulfate) pulp mills using Best Available Techniques	0.3 to 1.5	8 to 23	0.6 to 1.5	EC BREF 2001
Deinked mill using Best Available Techniques	<0.05 to 0.2	2.0 to 4.0	0.1 to 0.3	
Typical virgin copy paper mill	3.15	45.85	5.05	Paper Task Force 2002
Typical recycled copy paper mill	3.05	13.8	3.45	

References

European Commission BAT Reference (BREF). 2001. *Integrated Pollution Prevention and Control (IPPC) reference document on best available techniques in the pulp and paper industry.* Seville, Spain: European Commission Joint Research Centre. http://eippcb.jrc.es/reference/pp.html

Paper Task Force. 2002. *Paper Task Force recommendations for purchasing and using environmentally preferable paper.* http://epa.gov/epawaste/conserve/tools/warm/pdfs/EnvironmentalDefenseFund.pdf

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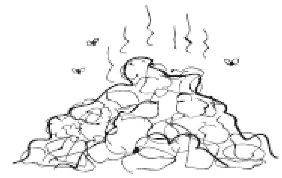

EFFECTS OF RECYCLED FIBER USE ON SOLID WASTE

Overview

In general, recycling reduces the amount of total municipal solid waste but increases the amount of solid waste from paper manufacturing itself. Overall, however, recycling tends to reduce life cycle solid waste loads. The solid waste-related benefits of recycling are paper grade-dependent.

Assessments of the impacts of recycling on solid waste should address impacts on a) municipal solid waste generation, b) wastes from manufacturing, and c) the options for managing solid wastes.

A major U.S. study of all solid waste generated through the life cycle suggests that recycling results in lowered solid waste across the range of all grades of paper and paperboard.

When looking at solid waste from paper manufacturing itself, recycling can result in equal or larger amounts of solid waste compared to virgin mills making the same products.

When considering these aspects in the context of comparing recycled and virgin fiber, note that trade-offs undertaken at an individual mill site ultimately have cascading effects through the overall industry's fiber cycle. Given that the recycled and virgin fiber cycles are inherently interrelated [See Overview], shifts in environmental aspects due to changes in the usage of one fiber type versus another result in shifts elsewhere in the fiber cycle. Life cycle assessment (LCA) is a tool that can help examine these interactions. LCA, particularly in the context of looking at the manufacturing of recycled versus virgin fiber pulp, is discussed in NCASI Technical Bulletin No. 1003.

More information

Municipal solid waste generation

Wastes from manufacturing

Options for managing solid wastes

Life cycle results for one major U.S. study

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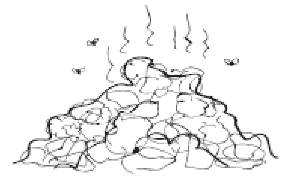

SOLID WASTE

EFFECTS OF RECYCLED FIBER USE ON SOLID WASTE

Municipal Solid Waste Generation

The paper and paperboard that is recovered for recycling comes from a variety of sources. In some cases, it is difficult to know whether in the absence of recycling the recovered material would have been disposed – and if disposed, whether it would have been landfilled or handled some other way. Because about 80% of non-recovered municipal solid waste (MSW) in the U.S. is landfilled (USEPA n.d.), it is often assumed that new supplies of recovered fiber will be diverted from landfills. It is important, however, to understand that increased demand in one sector of the industry will not only help divert fiber from landfills, it will also increase competition for current supplies of recovered fiber, potentially causing reductions in recovered fiber use in other sectors of the industry (Metafore 2006).

From the standpoint of understanding the trade-offs and co-benefits of recycling, it is usually not necessary to become involved in the “pre-consumer” vs. “post-consumer” debate because essentially all pre-consumer material is already being recycled due to its relative cleanliness and ease of collection. Incremental increases will probably be derived from what are commonly considered “post-consumer” sources. On average, at the national level, increasing the use of recovered fiber by one ton is often assumed to reduce the amount of municipal solid waste being landfilled by 0.8 tons since about 80% of non-recovered MSW is landfilled. As implied above, this does not consider the potential for some sectors to shift from recovered fiber to virgin fiber, as they might do if competition for recovered fiber resulted in higher prices for this source of raw material. In addition, the benefits estimated for national average conditions do not represent the situation in specific regions because MSW management practices vary significantly from place to place. The implications of MSW management methods are discussed in more detail in the options for managing solid waste section.

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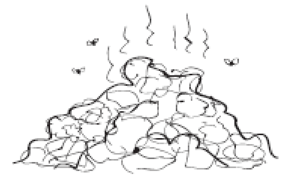

SOLID WASTE

EFFECTS OF RECYCLED FIBER USE ON SOLID WASTE

Wastes from Manufacturing

The manufacture of paper and paperboard results in the generation of solid waste. The amounts generated vary among mills depending on a number of factors, including the type of products made and the manufacturing processes being used. In considering the co-benefits and trade-offs between increased recycling and solid waste generation, one must consider the differences in solid waste generation between virgin and recycling mills making comparable grades. It should be noted that in terms of hazardous waste generated in pulp, paper, and paperboard manufacturing, the amounts are very small in all cases.

The following table contains representative paper and paperboard mill solid waste generation rates. It is important to understand that for some grades, linerboard and medium/fluting for instance, it is increasingly rare for products to be made only of virgin fiber. In addition, the total amounts of solid waste will be influenced by factors other than whether the mill is a recycled fiber mill or a virgin mill. Ash is generated in the burning of some fuels, with the amounts depending primarily on the selection of fuel. Also, biological sludges are generated at many mills with secondary wastewater treatment plants, with the amounts varying depending, in part, on the design and operation of the treatment plant. The generation of these additional solid wastes is only loosely related to whether the mill is a virgin or recycled mill, meaning that they are less important than process-related solid wastes in considering solid waste trade-offs.

The information in the table illustrates that for products consisting mostly of bleached chemical pulp fiber (e.g., tissue, toweling, copy paper) the amount of solid waste from recycled mills is much greater than the amount from virgin manufacturing, with recycled production resulting in approximately 200 to 300 kg per tonne of additional mill-related solid waste. Statistical analysis of NCASI site-specific data confirms that solid waste generation from recycled mills is higher in these types of recycled mills.

For grades of paper composed primarily of mechanical fibers (e.g., newsprint), recycled production results in about 150 kg per tonne more solid waste than virgin production. Statistical analysis of NCASI site-specific data confirms that solid waste generation is higher at recycled newsprint mills compared to virgin newsprint mills.

In the case of containerboard and recycled paperboard as well as bleached board, the differences between virgin and recycled production are much smaller. The data below suggest that solid waste generation rates at virgin and recycling mills in these sectors overlap to a great degree. Statistical analysis of NCASI site-specific data confirms this observation.

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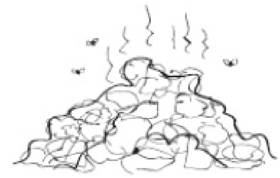
ENVIRONMENTAL FOOTPRINT COMPARISON TOOL

A tool for understanding environmental decisions related to the pulp and paper industry



SOLID WASTE

EFFECTS OF RECYCLED FIBER USE ON SOLID WASTE

Options for Managing Solid Wastes

To address the effect of recycling on pulp and paper industry solid waste management, one must decide whether the concern is total solid waste generation or the amounts of solid waste that are not beneficially used. If one is concerned only with those wastes that are not beneficially used, it becomes necessary to define what constitutes beneficial use.

Of the solid waste that is not recycled (or composted) in the U.S., 82% is landfilled and 18% is burned for energy recovery (USEPA 2011). Burning with energy recovery in waste-to-energy plants is a practice that is often considered to constitute a beneficial use (USEPA n.d.). The benefits of recycling in reducing solid waste will, therefore, depend on (a) whether one is concerned with solid waste generation or only with MSW that is not beneficially used, (b) whether burning for energy is considered, like recycling, to be a beneficial use, and (c) on the specific waste management practices in localities where materials are discarded.

These same considerations apply to the management of mill wastes. In the U.S., NCASI site-specific data for 2010 indicate that about 60% of solid waste from U.S. pulp and paper mills is disposed of in landfills, a level that has remained fairly stable since 2000 (AF&PA 2002 *Environmental Health & Safety Report*), with the rest being beneficially used as fuel, land applied as a soil conditioner, and used in other beneficial use applications. Specific mills, however, may landfill all or none of their solid waste. Therefore, the benefits of recycling in reducing solid waste will also depend on (a) whether one is concerned with mill solid waste generation or only with mill solid waste that is not beneficially used, (b) whether burning for energy and land application are considered to be beneficial uses, and (c) the specific solid waste management practices of the mills involved.

On average across the U.S., because recycling removes much more material from MSW landfills than it adds to mill waste landfills, the overall effect is, in most cases, a significant reduction in landfilled solid waste.

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Table R18.

Type of Paper or Paperboard	Solid Waste Generation (dry kg per tonne)*	Reference
Recycled graphic paper (e.g., newsprint) from news and magazines	150 to 200	Paulapuro 2000
Recycled graphic paper (e.g., newsprint) from "superior grades"	100 to 250	Paulapuro 2000
Recycled newsprint	376**	Paper Task Force 2002
Paper (e.g., newsprint) from mechanical pulp (includes solid waste from pulping and papermaking)	20 to 30	Springer 2000
Virgin newsprint	215**	Paper Task Force 2002
Hygienic paper (tissue and toweling)	280 to 400	Gottsching and Pakarinen 2000
Market deinked pulp	320 to 400	Gottsching and Pakarinen 2000
Recycled office paper	376**	Paper Task Force 2002
Virgin kraft pulping and papermaking	25 to 35	Springer 2000
Virgin office paper	197**	Paper Task Force 2002
Recycled containerboard (linerboard and medium/fluting)	40 to 90	Gottsching and Pakarinen 2000
Recycled containerboard (corrugated)	105**	Paper Task Force 2002
Virgin kraft or semi-chemical pulping and board production	25 to 40	Springer 2000
Virgin containerboard (corrugated)	108**	Paper Task Force 2002
Recycled boxboard, tube stock and other recycled paperboard	40 to 90	Gottsching and Pakarinen 2000
Recycled paperboard	105**	Paper Task Force 2002
Virgin unbleached kraft or semi-chemical pulping and board production	25 to 40	Springer 2000
Virgin unbleached board	86**	Paper Task Force 2002
Coated recycled paperboard	105**	Paper Task Force 2002
Virgin bleached board	96.5**	Paper Task Force 2002

*Except as noted, does not include biological sludge from wastewater treatment or ash from fuel combustion.
** Includes all mill solid wastes, including ash, biological wastewater treatment sludge and other solid wastes.

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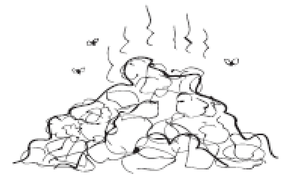

EFFECTS OF RECYCLED FIBER USE ON SOLID WASTE

Life Cycle Results for One Major U.S. Study

The Paper Task Force report (Paper Task Force 2002) contains life-cycle study results characterizing all of the solid wastes landfilled along the value chain for virgin and recycled paper, including solid waste resulting from the generation of purchased electricity (which, due to coal burning at utilities, contributes a significant amount to the life cycle solid waste loads). The results, shown in the following table, suggest that recycling reduces life-cycle solid waste generation for all grades. The smallest differences between virgin and recycled production are for grades like office paper (copy paper) where the recycling process involves the deinking of recovered paper consisting largely of chemical pulp fibers, often containing significant quantities of inorganic filler or coating.

The Paper Task Force results are for average U.S. waste management methods and do not differentiate between landfilling and beneficial use of mill and utility solid wastes. The impacts of removing beneficially used industrial solid waste from the analysis are uncertain, but because so much of the benefit from recycling derives from impacts on municipal solid waste (MSW), a revised analysis accounting for beneficially used industrial waste would likely continue to indicate solid waste benefits for recycling. The results could be different, however, in situations where the alternative to recycling is burning for energy.

Table R19.

Product	kg Solid Waste per Tonne of Paper Disposed/Recycled		
	Virgin Production Plus U.S. Average Waste Management	Recycled Production Plus Recycling	Difference
Newsprint	1,239	570	669
Corrugated	970	269	701
Office paper	1,142	578	564
Recycled folding carton paperboard vs. coated virgin unbleached kraft)	949	290	659
Recycled folding carbon paperboard vs. virgin bleached kraft board	1,121	290	831

Source: Paper Task Force 2002.

References

Paper Task Force. 2002. *Paper Task Force recommendations for purchasing and using environmentally preferable paper.* http://epa.gov/epawaste/conserve/tools/warm/pdfs/EnvironmentalDefenseFund.pdf

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