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SOLID WASTE MANAGEMENT PRACTICES IN THE U.S. PAPER INDUSTRY - 1995

TECHNICAL BULLETIN NO. 793

SEPTEMBER 1999

Acknowledgements

This technical bulletin and the database from which it was drawn would not exist had it not been for the unstinting efforts of a number of individuals. Laurel Eppstein, Senior Research Associate at NCASI's Central-Lake States Regional Center, helped to design the survey. She designed, populated, and audited the database into which survey data were placed, and she performed almost all the data analysis required to prepare this bulletin and also to respond to the numerous individual company requests that have been satisfied using the data. Mary Kay Lynde-Maas, former NCASI Research Engineer, carried out the critical steps of designing and implementing the mill categorization scheme. She also prepared the first draft of this bulletin. Kevin Kahmark, NCASI Research Associate, also assisted in the categorization effort by helping to collect published information on facilities that did not respond to the survey. Jay Unwin and Reid Miner helped design the survey and wrote much of the text. Anna Aviza, Administrative Assistant at NCASI's Central-Lake States Regional Center, provided extensive technical editing and she finalized the bulletin for publication.

For more information about this research, contact:

Jay Unwin
Regional Manager
NCASI Central-Lake States Regional Center
Western Michigan University
Kalamazoo, MI 49008
(616) 387-5128
junwin@ncasi.org

Reid Miner
Vice President, Water & Pollution Prevention Programs
NCASI
P.O. Box 13318
Research Triangle Park, NC 27709
(919) 558-1999
rminer@ncasi.org

For information about NCASI publications, contact:

Publications Coordinator
NCASI
P.O. Box 13318
Research Triangle Park, NC 27709-3318
(919) 558-1999
publications@ncasi.org

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PRESIDENT'S NOTE

An important element of NCASI's Technical Studies Program is the collection and publication of information that documents the forest products industry's environmental performance. Efforts in this area include the ongoing documentation of the industry's generation and management of solid residues from manufacturing operations. This information is used extensively in company benchmarking activities. In fact, as of the date of publication, the data summarized in this report have been used to respond to more than 100 individual requests from NCASI member companies. (Appendix B contains much of the category-specific information most useful for this application, and member companies are welcome to request more specific queries of the data.) Also, in a broader context, this information has been used in the industry's ongoing "proof of performance" activities. The availability of accurate information has helped the industry respond to regulatory questions about quantities generated, land disposal, hazardous waste, and even global climate change.

This technical bulletin, based on an extensive body of data collected over more than two decades, is the latest report in a series on solid waste management. It provides information on solid residues from the forest products industry that is not available elsewhere in any form.

The data show that, although the industry's manufacturing operations generate a considerable amount of solid residues, those residues are managed in a responsible manner. Most noteworthy is the observation that reliance on land-based disposal (landfills and lagoons) has been steadily decreasing, while beneficial uses have been increasing.

Ronald A. Yeske

September 1999

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ABSTRACT

NCASI collected solid residue generation and management data for 1995 from 285 U.S. pulp and paper facilities representing approximately 70% of that year's U.S. pulp and paper production. Facilities were organized into 17 product-fiber categories for reporting purposes. Procedures were used to extrapolate to non-responding facilities and to account for facilities that did not fit a single product-fiber category. Generation rates, quantity generated, and management methods were determined both category-by-category and overall for wastewater treatment residuals, ash, miscellaneous residues, and total solid residues. Results showed generation by the U.S. pulp and paper industry of a total of 14.6 million dry tons of solid residues in 1995. This was comprised of 5.83 million dry tons of wastewater treatment residuals, 2.81 million dry tons of ash, and 5.91 million dry tons of miscellaneous solid residues. Generation rates were similar to or, in some cases, somewhat larger than they were in 1988 when the last survey was done. Total solid residue quantity increased about 24% probably due primarily to production increases and secondarily to the use of lower quality recovered fiber furnish. Management by land-based methods was still predominant in 1995. However, the trend away from land-based management toward beneficial use noted in 1988 continued through 1995. The data provided insight into the size, age, remaining life, cost, and groundwater monitoring of land-based solid residue management units.

KEYWORDS

residuals, residues, sludge, solid waste, ash, dewatering, landfill, burning, land application, beneficial use, disposal, costs, generation rates, groundwater monitoring

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 641 (September 1992). *Solid waste management and disposal practices in the U.S. paper industry.*

Technical Bulletin No. 612 (July 1991). *Full-scale experience with the use of screw presses for sludge dewatering in the paper industry.*

Technical Bulletin No. 603 (February 1991). *Progress in reducing water use and wastewater loads in the U.S. paper industry.*

Special Report No. 83-09 (August 1983). *A compilation of data on the nature and performance of wastewater management systems in the pulp and paper industry.*

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SOLID WASTE MANAGEMENT PRACTICES IN THE U.S. PAPER INDUSTRY - 1995

1.0 INTRODUCTION

Since 1976 NCASI has published summary statistics describing water use, wastewater loads, and solid waste management and disposal practices in the U.S. pulp and paper industry (NCASI 1976, 1979, 1983, 1991, 1992, Miner and Unwin, 1991). In 1996 NCASI once again solicited information from its membership on current solid waste management practices. A detailed questionnaire was distributed in May 1996 requesting information for calendar year 1995. The response to the NCASI questionnaire and supplemental data from an earlier survey done by the Recycled Paperboard Technical Association (RPTA 1993) yielded data for 285 mills representing approximately 70% of the U.S. industry's total production of paper, paperboard, and market pulp.

This report summarizes the major findings from the data that provide a picture of the industry's solid waste generation and management practices in 1995. The data are held in an electronic database that can be queried in a wide variety of ways. To date, approximately one hundred information requests from member companies have been satisfied by querying the database in various ways, usually in support of a mill or corporate benchmarking exercise. In addition, the information has been used to assist industry issue managers in responding to a number of regulatory issues.

1.1 Categorization and Industry Totals Estimation

In order to facilitate reporting of results for specific sectors of the industry and also to help refine extrapolation of survey responses to the entire industry, NCASI organized industry facilities into seventeen categories according to the type of product and the fiber source. The product portion of the categorization is based on the American Forest & Paper Association's (AF&PA) categorization scheme (AF&PA 1996). This was done to better align the reporting of environmental facts with the reporting of industry production statistics.

Even seventeen categories are not sufficient to represent fully the diversity of product-fiber combinations in the U.S. industry. However, the types and relative amounts of product-fiber combinations reported by the survey respondents limited the number of categories that could be defined from the data. The criteria for classification in a particular category were generally that 70% of the product manufactured and 70% of the fiber source for that product should be as indicated in the category name. About 85% of the facilities included in the database (respondents and non-respondents) met these "single category" criteria. Facilities that did not fit in a single category were treated as "complex" mills best characterized by combinations of two or more of the 17 categories. Non-responding mills were categorized using information from an industry directory (Anonymous 1996) and other unpublished sources.

Some of the 17 product-fiber categories include more than one fiber source. Those linked with the conjunction "or" represent criteria where one or the other of the fiber types was at least 70% of the total for a particular respondent. Those linked with the conjunction "plus" indicate that for some facilities in the category, the two fiber sources may have had to be added together to reach 70%, while other facilities in the category may have reached 70% with just the first fiber listed.

Since not every mill responded to the survey, quantities of materials reported in the survey had to be projected into estimates for the entire industry. For residues other than ash, this was done by determining median category-specific, production-normalized generation rates for the materials based on data from single-category respondents to the survey. These medians were then used along

with production information for non-responding mills to give preliminary estimates of quantities of the various materials generated by non-responding mills in each category. The preliminary estimated quantities were corrected to final estimates using a correction factor to account for the difference between production information available for non-respondents, and actual aggregate production for the category reported by AF&PA (1996). The final estimates for non-respondents were added to the quantities reported by responding mills in each category to yield estimates of industry total quantities for each category. Category totals were then summed to give an overall estimate of the total industry quantity. See Appendix A for more detail on the categorization and estimation methodology, including an explanation of the handling of complex mills that did not fit a single category.
See Section 3.2 for a discussion of ash quantity estimation.

1.1.1 *Statistical Procedures*

Statistics expressed on a production-normalized basis (e.g., lb./ton) are calculated using dry pounds of the material in question and the shipped tons of final product. Product tonnage is at as-shipped moisture content (air-dried for market pulp). Most data are rounded to three significant figures or fewer. Rounding error sometimes causes minor discrepancies such as totals that are not exactly the sum of the components or percentages that do not add up to 100%. Preliminary statistics released from the survey earlier (Lynde-Maas, 1997) sometimes differ slightly from those presented here due to subsequent database revisions and refinements.

Most of the statistics reported here come from unknown population frequency distributions, though skew to the right (i.e., long tail on the right side) is often apparent. Ideally, distributions would be characterized (e.g., normal, lognormal) and inferential methods appropriate for each distribution would be used. However, characterization of distributions is hampered by statistically small sample sizes. Therefore, non-parametric inferential statistical methods are used. These procedures are designed to give valid results regardless of the shape of the frequency distribution from which samples are drawn. Medians are used to report central-tendencies of values of interest. When statistical comparisons are done, the non-parametric analog of Student's t test, the Mann-Whitney test, is used (NCASI 1985). Probabilities reported for such tests (e.g., "$p=0.24$") are the probabilities that the observed difference could have occurred when the actual values of the parameters being compared were equal. Normal practice is to consider a difference statistically significant that probability is less than 5% ($p < 0.05$).

2.0 WASTEWATER TREATMENT PLANT RESIDUALS

Wastewater treatment plant solid residuals are those solid materials collected in the process of treating water used in the mill prior to its release into the environment. Typically, these materials consist of solids collected in primary treatment (separation of solids from raw wastewater) and secondary treatment (biological treatment followed by clarification to separate biosolids). Often these primary and secondary residuals are combined to facilitate handling. This section discusses the generation rates of these materials, their estimated quantities, and their management.

2.1 Wastewater Treatment Plant Generation Rates

Wastewater treatment plant solid residuals generation rates by production category, based on survey responses, are summarized in Table 1. More detailed statistics are in Table B1 of Appendix B. Intermittently dredged materials are not included in the table because some respondents indicated that such materials did not always consist solely or even primarily of wastewater treatment residuals. Sufficient data to calculate medians was provided by 196 respondents.

Table 1. Wastewater Treatment Residuals Generation Rates
(dry lb. per short ton of shipped product)

Product-Fiber Category	Median	Min.	Max.	n
Bleached Container & Box - Bleached Kraft	68.7	19.2	211	8
Construction – Any Fiber	5.40	2.74	53.1	3
Corrugating Medium – Nondeinked	32.7	0.326	132	5
Corrugating Medium – Semi-chemical	81.6	68.6	297	4
Dissolving Pulp – Bleached Kraft or Sulfite	136	48.3	315	4
Market Pulp – Bleached Kraft or Sulfite	41.9	14.5	251	7
Newsprint – Deinked	537	229	793	4
Newsprint – Mechanical plus Deinked	204	102	283	5
Printing & Writing – Bleached Kraft	126	20.5	325	22
Printing & Writing – Mechanical plus Other	121	85.1	234	8
Printing & Writing – Purchased	88.1	22.1	358	14
Printing & Writing – Sulfite	160	76.4	285	6
Packaging & Industrial – Purchased	52.9	41.2	791	8
Recycled Container & Box – Nondeinked	49.7	1.11	480	29
Tissue & Toweling – Deinked	867	450	994	5
Tissue & Toweling – Nondeinked	179	106	313	4
Unbleached Container & Box – Unbleached Kraft	36.3	3.81	180	13
All respondents regardless of category[a]	86.9	0.326	994	196

[a] All reporting mills, including complex mills which do not fit a single category. Not all 285 respondents provided useable information.

The median generation rate for all respondents over all categories was 87 dry pounds per ton of final product (92 lb/ton if intermittently dredged residuals are included).

The individual primary and secondary residuals generation rates are given in Appendix B, Tables B3 and B4. As expected, fewer mills reported generation of secondary residuals (n=78) than primary (n=189).

2.1.1 *Trends in Generation Rates*

The median generation rates for 1988 and 1995 are compared in Table B2 of Appendix B. The overall median generation rate decreased between 1988 and 1995 from 96 dry lb./ton to 87 dry lb./ton. This change was not, however, statistically significant (Mann-Whitney test, p=0.31).

The median primary and secondary residuals generation rates (see Tables B3 and B4, Appendix B) across all respondents were 80 and 24 dry pounds per shipped ton of product, respectively, in 1995, and 79 and 31 tons, respectively, in 1988.

2.2 Wastewater Treatment Plant Residuals Quantity

Overall total quantity and totals by category were estimated as discussed in Section 1.1 and Appendix A.

2.2.1 *Estimated Total Industry Quantity*

Table 2 summarizes the quantities estimated for each of the 17 product-fiber categories with the total for all U.S. mills in the last line. Details are given in Table A1 of Appendix A.

Table 2. Estimated Quantity of Industry Wastewater Treatment Residuals in 1995

Product - Fiber Category	Estimated Thousands of Dry Tons[a]
Bleached Container & Box - Bleached Kraft	354
Construction - Any Fiber	13.0
Corrugating Medium - Nondeinked	51.1
Corrugating Medium - Semi-chemical	201
Dissolving Pulp - Bleached Kraft or Sulfite	122
Market Pulp - Bleached Kraft or Sulfite	165
Newsprint - Deinked	345
Newsprint - Mechanical plus Deinked	462
Printing & Writing - Bleached Kraft	1,080
Printing & Writing - Mechanical plus Other	217
Printing & Writing - Purchased	276
Printing & Writing - Sulfite	142
Packaging & Industrial - Purchased	64.9
Recycled Container & Box - Nondeinked	230
Tissue & Toweling - Deinked	1,540
Tissue & Toweling - Nondeinked	40.1
Unbleached Container & Box - Unbleached Kraft	530
Total	5,830

[a] Rounded to three significant figures

The best available estimate of the total quantity of wastewater treatment residuals generated by the U.S. pulp and paper industry in 1995 is 5.83 million dry tons.

Figure 1 shows the geographic distribution of wastewater treatment residuals generated by the industry in 1995. This distribution generally reflects the distribution of pulp and paper manufacturing in the United States.

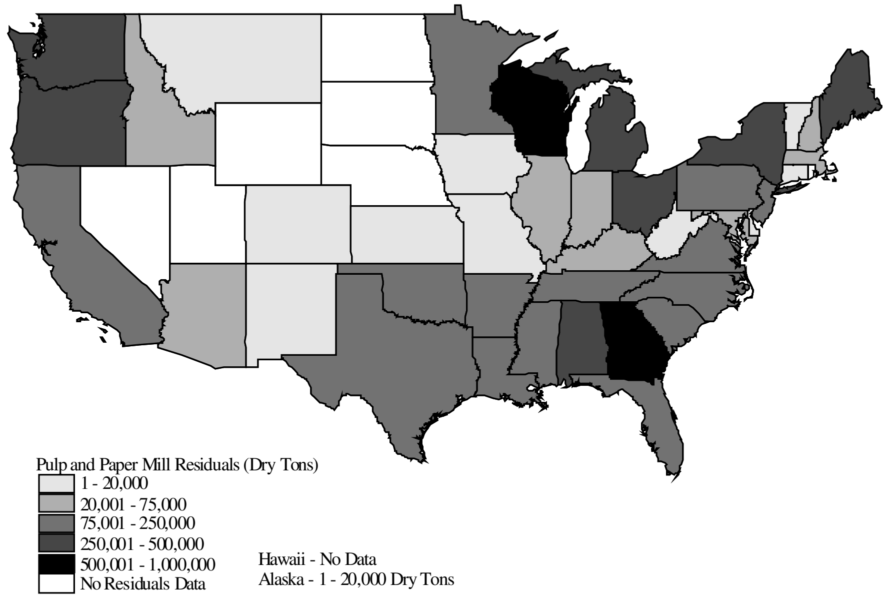

Figure 1. Geographic Distribution of Residuals by State

2.2.2 *Trend in Quantity*

The estimated total quantity of residuals in 1988 was 4.6 million dry tons (NCASI 1992). The 1995 estimate of 5.83 million dry tons represents an increase of about 1.2 million tons or 26%. The increase is due in part to an approximately 17% increase in manufacturing over the period. Some of the increase is also probably due to increased use of recovered fiber across the industry and use of lower grade (and lower yield) recovered fiber by some producers.

Figure 2 illustrates the trend in quantity of residuals since 1975 when the first reliable data were collected.

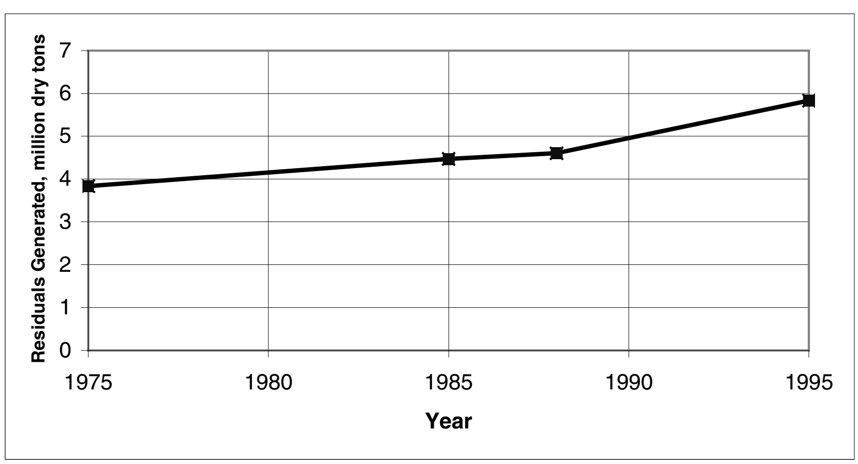

Figure 2. Trend in Wastewater Treatment Residuals Quantity 1975-1995

2.2.3 *Quantities by Type of Residual*

A total of 3.8 million dry tons of wastewater treatment residuals of all types was reported by 166 respondents to the NCASI survey. The RPTA survey included responses from 50 mills generating about 0.2 million dry tons, but these responses were generally not detailed or specific enough to allow determination of the quantities of residuals generated by type. Thus, only NCASI survey responses were used in the following analysis.

About 3.3 million dry tons (87% of the total) of the reported residuals were from primary treatment of raw wastewater. The amount of secondary biosolids reported was only a tenth of the amount of primary, about 0.32 million dry tons (8.6%). The remainder, about 0.19 million dry tons (5%), was intermittently dredged material. Figure 3 summarizes these findings.

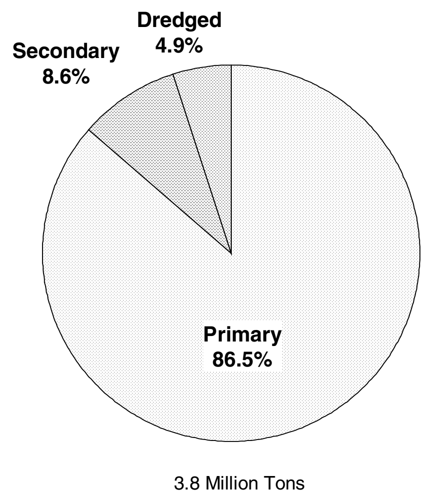

Figure 3. Wastewater Treatment Residuals Generated Quantities by Type

2.3 Wastewater Treatment Plant Residuals Management Practices

Management of the residuals refers to the ways in which they are handled and their final disposition. For wastewater treatment residuals, relevant questions in addition to final disposition relate to how they are combined and how they are dewatered.

2.3.1 *Combination of Residuals for Management*

Figure 3 summarizes the quantities and types of residuals generated, but does not reflect the nature of the materials as they were ultimately managed. Many respondents (66) reported production of both primary and secondary residuals. Most of these (62 respondents or 94%) combined the primary and secondary residuals prior to further management. The median reported percentage of biosolids in the combined residuals was 15.7%.

In terms of dry tonnage *as managed*, 54% was combined (primary plus secondary), 40% was primary alone, 5% was intermittently dredged material, and 1% was secondary alone. See Figure 4. Note, because respondents to the RPTA survey did indicate the composition of residuals as managed, it was possible to include their responses when calculating the percentages. Thus, the tonnage basis given in Figure 4 is slightly higher than that in Figure 3 which included only NCASI survey responses.

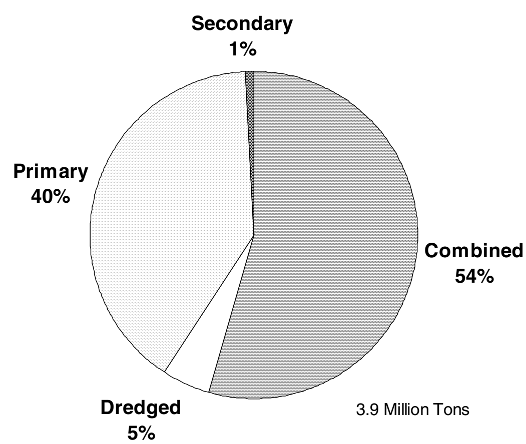

Figure 4. Wastewater Treatment Residuals Composition as Managed

2.3.2 *Dewatering*

One hundred fifty-one mills from the NCASI survey reported some dewatering (mechanical or land-based) of wastewater treatment residuals. The RPTA survey did not ask about dewatering. Of all wastewater treatment residuals reported by survey respondents, 93% were reportedly subjected to some dewatering. For most (98%) of the dewatered residuals, the dewatering method used and the amount of material dewatered were specified.

Table 3 reports the dewatering method used on the basis of percent of dry tonnage dewatered. Primary and combined residuals were predominantly dewatered using either belt or screw presses. Overall, 84% of residuals were dewatered either with belt filter presses or screw presses.

Table 3. Residuals Dewatering Methods - Percent of Dewatered Tonnage

Dewatering Method	Combined	Primary	Secondary	Dredged	Total[a]
Belt Filter Press	60%	36%	96%	14%	50%
Screw Press	38%	34%	NR	28%	36 %
Land-based[b]	NR	17%	NR	58%	8%
Vacuum Filter	1.7%	10%	NR	NR	5%
V-Press	0.2%	0.5%	NR	NR	0.3%
Centrifuge	NR	2%	NR[c]	NR	0.8%
Other[d]	NR	0.2%	4%	NR	0.1%

NR = None Reported
[a] Percentages total more than 100% due to rounding.
[b] Land-based units include lagoons, drying beds, etc.
[c] One centrifuge was reportedly dewatering secondary residuals, but no quantity was reported.
[d] “Other” units include side hill screen, mixing with paper, and unspecified presses.

For the small amount of secondary biosolids that were dewatered uncombined, belt filter presses were used almost exclusively. More than half of the dredged material was dewatered using land-based methods.

Table 4 details the number (and percentage) of responses indicating use of each dewatering method on each type of residual. The number of responses adds up to more than the 151 mills providing responses because some mills reported using more than one method.

Table 4. Number and Percent of Responses Reporting Use of Residuals Dewatering Methods

Dewatering Method	Combined	Primary	Secondary	Dredged	All[a]
Belt Filter Press	39 (21%)	36 (19%)	4(2.1%)	7 (3.7%)	86 (46%)
Screw Press	24 (13%)	31 (16%)	NR	2 (1.1%)	57 (30%)
Land-based[a]	NR	7 (3.7%)	NR	12 (6.4%)	19 (10%)
Vacuum Filter	2 (1.1%)	11 (5.9%)	NR	NR	13 (6.9%)
V-Press	3 (1.6%)	5 (2.7%)	NR	NR	8 (4.3%)
Centrifuge	NR	2 (1.1%)	1 (0.53%)	NR	3 (1.6%)
Other[c]	NR	1 (0.53%)	1 (0.53%)	NR	2 (1.1%)

NR = None Reported
[a]Percentages total to less than 100% due to rounding.

The findings in Table 3 are similar to what was reported for 1988 (NCASI, 1992) in that mechanical dewatering continues to predominate with belt filter presses leading the way. Since 1988, however, the percentage of mills reporting use of screw presses has nearly doubled from 17% to 30%. Use of vacuum filters declined from 12% in 1988 to less than 7% in 1995. Use of all other methods either declined slightly or remained about the same.

Figure 5 depicts the average percent solids attained by the different dewatering methods applied to various types of residuals. Screw presses attained the driest cake, with over 40% solids for all materials dewatered. Land-based dewatering of dredged materials achieved an average of 40% solids, but it performed poorly on primary residuals (26% solids). The averages for belt filter presses on combined and primary residuals were over 30% solids. Belt filter presses used on secondary biosolids alone achieved an average 22% solids content, much higher than the only other method reportedly used, a centrifuge. Centrifuges slightly outperformed belt filter presses on primary residuals. Vacuum filters performed somewhat worse than belt filter presses on combined and primary residuals. The overall average percent solids achieved by all methods on all residuals types was 34% solids (median = 35%).

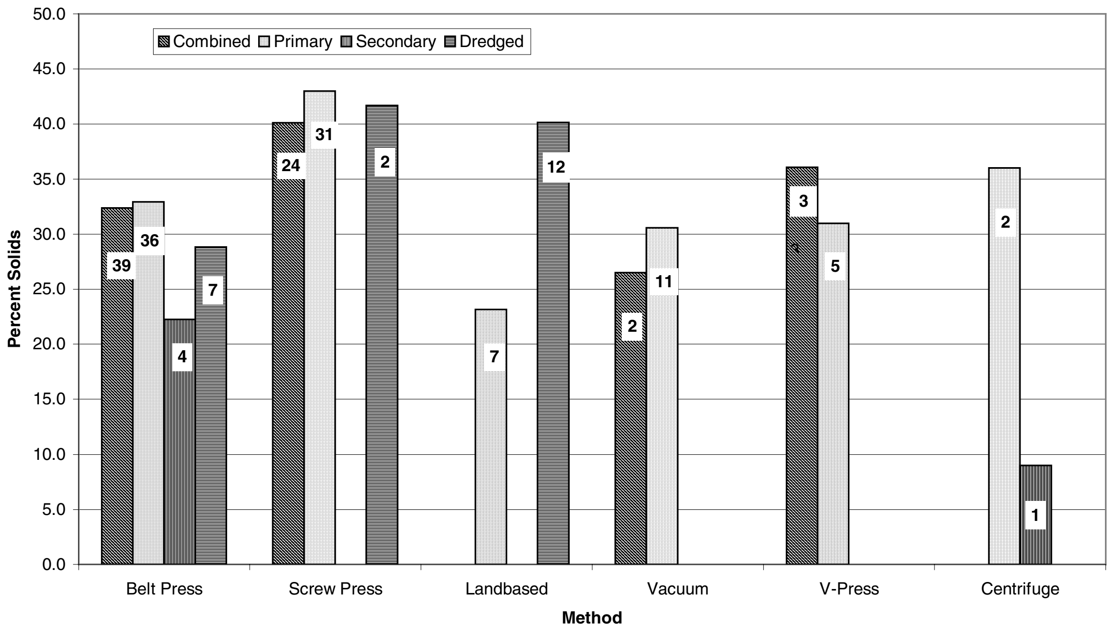

Figure 5. Average Percent Solids by Dewatering Method and Residuals Type

2.3.3 *Management for Final Disposition*

A total of two hundred twelve respondents reported their final disposition management practices for wastewater treatment solid residuals. However, nine of those respondents from the RPTA survey included secondary fiber pulping rejects with the quantities of wastewater treatment residuals reported. Those quantities were therefore excluded from the following analysis. The remaining 204 mills generated almost 98% of the residuals tonnage reported.

Table 5 summarizes how individual residuals types were managed for final disposition.

Table 5. Residuals Management Practices for Final Disposition

Residual Type	Thousand Dry Tons Reported	Landfill/ Lagoon	Land Apply	Burn	Other Beneficial Use	Recycle/ Reuse in Process
Primary	1,541	51%	12%	19%	9.9%	8.4%
Secondary	32.50	51%	18%	3.1%	18%	9.7%
Combined	2,141	50%	11%	32%	2.6%	3.9%
Dredged	181.1	58%	22%	20%	NR	NR
Total 1995	3,897	51%	12%	26%	5.5%	5.6%

NR = None Reported

Figure 6 summarizes graphically the 1995 totals from the last line of Table 6.

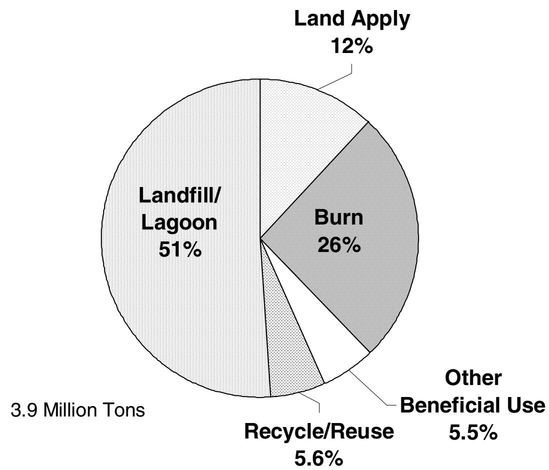

Figure 6. Final Disposition Management Methods for Wastewater Treatment Residuals

Figure 7 depicts trends in final disposition management since 1979. Data for 1979 and 1988 are from NCASI (1992).

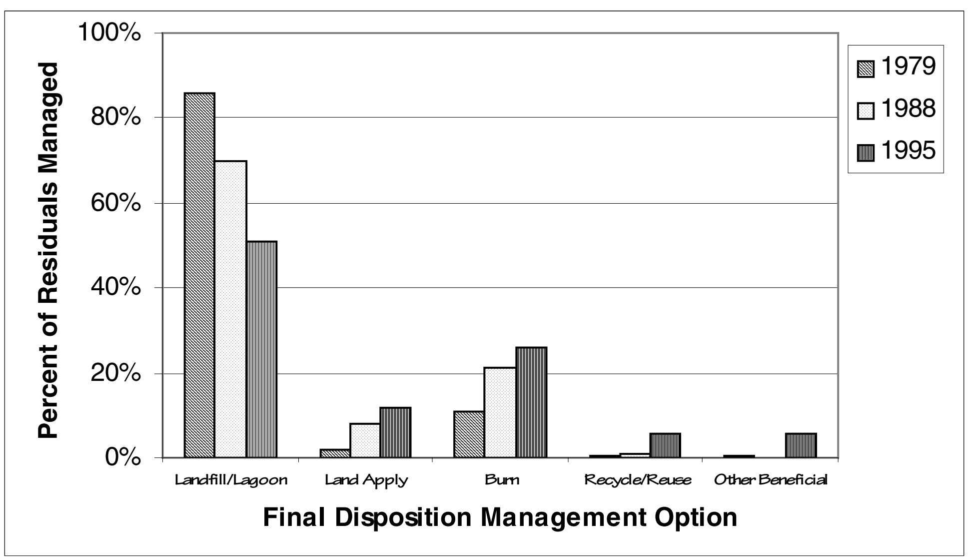

Figure 7. Trends in Management for Final Disposition of Wastewater Treatment Residuals 1979-1995

This figure shows clearly that while land disposal in landfills and lagoons has been decreasing, beneficial uses such as land application, burning (usually with energy recovery), and recycle/reuse have all been increasing.

Category-specific data on management for final disposition are presented in Table B5 of Appendix B.

3.0 ASH

The pulp and paper industry uses substantial quantities of energy, much of which is generated on site either from purchased fuels, liquor recovery, or burning of wood, bark, and other materials generated in the manufacturing process. This energy generation results in production of combustion ashes that require proper management. This section examines the generation rates of combustion ash, the quantity of ash generated, and the ways in which the ash was managed in 1995.

3.1 Ash Generation Rates

The most straightforward way to estimate ash generation rates is on the basis of the types and amounts of fuel burned. Of the fuels used by the pulp and paper industry in significant quantities, only three produce appreciable ash. These are coal, wood/bark, and wastewater treatment residuals. Because the NCASI survey asked for information on the amount of each type of fuel burned as well as the amount of ash produced, it is possible to derive fuel-specific ash generation rates (i.e., ash content) for 1995 from data supplied by facilities using only one type of fuel.

For the 25 respondents supplying fuel and ash quantities for wood/bark, the median ash generation rate was 5.0% on a dry wood basis (average 6.1%). Thirty facilities reporting for coal alone had a median ash generation rate of 9.5% (average 10%). No respondent reported burning residuals alone, so an ash generation rate for that material could not be derived. The survey did not solicit information on ash content of residuals being burned. However, other unpublished NCASI data on ash content of 74 different residuals samples yield a median ash content of 31.6% on a dry basis (average 30.6%).

Using survey responses, it is possible to calculate production-normalized generation rates for ash in each production category as was done for wastewater treatment residuals in Table 1. However, the reliability and even the meaning of such rates would be questionable. The rate of wastewater treatment residuals generation is much more closely tied to the production of final product than is the rate of ash generation. The latter depends not only on what is being produced, but also on how the energy used in the process is obtained. Two mills producing exactly the same product could have very different ash generation rates because one has a coal-fired boiler and the other has an oil-fired boiler. For these reasons, this methodology was not pursued.

3.2 Ash Quantity

An estimate of the quantity of ash generated by the U.S. industry in 1995 can be derived by multiplying fuel-specific ash generation rates from Section 3.1 by the total quantity of each fuel burned in 1995. This Technical Bulletin presents sufficient information to derive a quantity of wastewater treatment residuals burned. Table 2 indicates that 5.8 million dry tons of residuals were generated. Table 5 shows that, of the residuals for which final disposition was reported, 26% by weight was burned. Thus, an estimated 1.5 million tons of residuals were burned in 1995. NCASI (1997) reports quantities of wood/bark and coal burned by the U.S. industry in 1995. Table 6 summarizes the data and presents an estimate for total ash generation by the industry.

Table 6. Estimation of Total Ash Generated by the U.S. Industry in 1995

Fuel Type	Ash Content, % (dry weight)	Quantity Burned, million dry tons	Estimate, thousand dry tons[a]
Coal	9.49%	13.5	1,280
Wood/Bark	4.99%	21.0	1,050
Wastewater Treatment Residuals	31.6%	1.52	480
Total	--	36.0	2,810

[a] Rounded to three significant figures

The best available estimate of the quantity of ash generated by the U.S. pulp and paper industry in 1995 is 2.81 million dry tons. About 46% of the ash was from the burning of coal, 37% was from wood and bark, and 17% was from wastewater treatment residuals.

It is not uncommon for some ash to be sent to the wastewater treatment facility where it is removed in the primary clarifier. This ash then becomes part of the primary wastewater treatment residuals. The generation rates and quantities reported here have not been adjusted for this practice. The values reported refer to the total generation regardless of subsequent handling of the ash.

3.2.1 *Trend in Ash Quantity*

Reliable data on ash quantity are not available before 1988. Trends before that year cannot be examined.

The estimated quantity of ash reported by NCASI (1992) for 1988 was 3.6 million dry tons. However, this figure was calculated using average, rather than median, ash contents and it did not include ash from burning of wastewater treatment residuals. When the estimate is recalculated in a manner consistent with the estimate for 1995, the 1988 estimated quantity is 2.86 million tons, almost exactly the same as for 1995. Thus, the quantity of ash generated by the U.S. pulp and paper industry apparently did not change between 1988 and 1995.

This finding is corroborated by fuel consumption figures published by NCASI (1997) which show a slight decline in wood and coal consumption between 1990 and 1995. Using the ash contents in Table 6, these declines would have caused a decline in ash generation of about 0.13 million tons. The quantity of wastewater treatment residuals burned increased from slightly less than a million tons in 1988 (NCASI, 1992) to about 1.5 million tons in 1995 (see above). Using the median residuals ash content in Table 6, this increase in residuals burning would have caused generation of about 0.18 million more tons of ash, roughly offsetting the decrease due to less consumption of wood and coal. Hence, ash quantity between 1988 and 1995 would be expected to be essentially unchanged.

3.2.2 *Quantities by Type*

Table 6 summarizes the quantities and types of ash generated, but this does not reflect the nature of the materials as they were ultimately managed. Figure 8, based on data from 124 survey responses, gives a more representative picture of the nature of ashes generated in terms of the components in the mixtures actually managed.

Tire-Derived Fuel (TDF) and wastewater treatment residuals were usually burned with some combination of coal or wood. Coal and/or wood averaged 83% by weight of the fuel mix when TDF and/or residuals were also present. The percentages for TDF and residuals in the figure are for ash generated from a fuel mix in which TDF or residuals represented more than 5% of the weight of the fuel mix. The "Other" ash category includes ash from fuel mixes that were at least 5% by weight of any of a variety of fuels. Among the fuels named by several respondents were secondary fiber pulping rejects, red liquor solids, petroleum coke, peanut hulls, and recovery furnace ash.

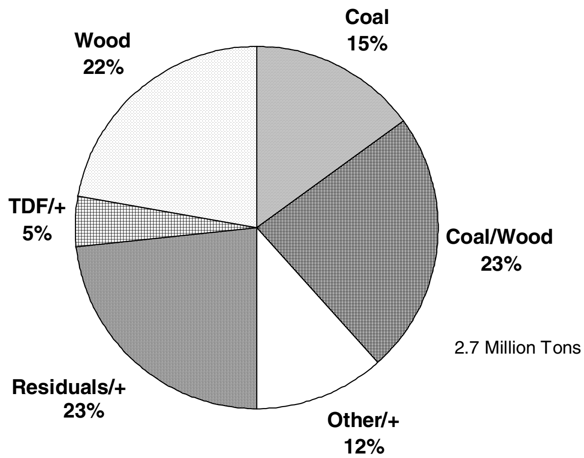

Figure 8. Ash Composition as Managed

3.3 Ash Management Practices

The ash management practices examined in the survey were dewatering of ash that is handled wet and management for final disposition.

3.3.1 *Dewatering of Wet Ash*

About a third of respondents providing ash information (42 of 145) indicated some dewatering method for ash that is handled wet. Most respondents (93%) reported using some kind of gravity drainage system for dewatering. The gravity systems were about evenly split between ponds (13), drainage pads (11), and other gravity systems such as screens in silos, sidehill screens, drainage from trucks, etc. (15). Six respondents reported using mechanical dewatering devices including three belt filter presses, two vacuum filters, and one plate and frame press, either alone or following gravity dewatering.

3.3.2 *Management for Final Disposition*

One hundred twenty respondents provided specific information on management for final disposition of 2.5 million dry tons of ash. Figure 9 depicts the percentages of ash reportedly managed using the various final disposition management options. Land disposal (landfill/lagoon) was the predominant option used in 1995. About equal amounts of ash went into construction and land application projects. Other beneficial uses included recycling/reusing in process, distributing unprocessed, use in by-products, and use in composting.

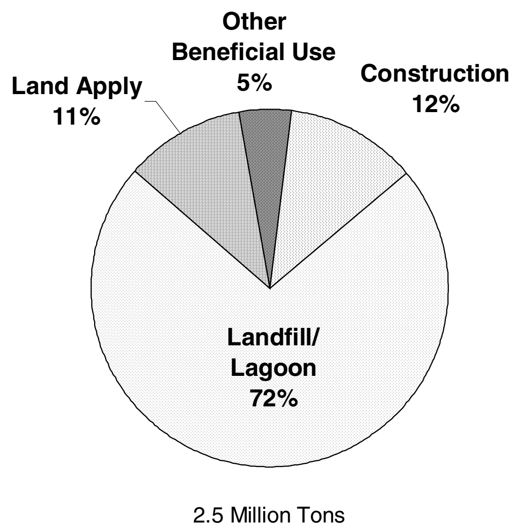

Figure 9. Management for Final Disposition of Ash in 1995

Figure 10 depicts the rather limited information available on trends in ash management. No reliable information is available before 1988, and the management options reported at that time did not distinguish between construction use and other beneficial uses. Therefore, in Figure 10, the beneficial use for construction is not shown separately.

This figure shows the same trend as for wastewater treatment residuals, albeit not as far advanced. That is, the industry is moving away from land disposal of ash in favor of beneficial use.

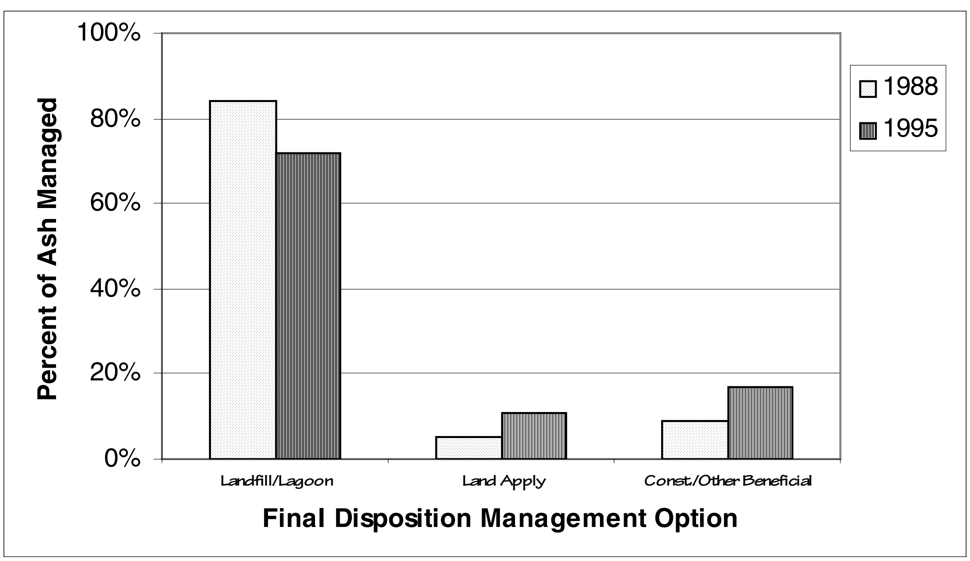

Figure 10. Trends in Management for Final Disposition of Ash 1988-1995

4.0 MISCELLANEOUS SOLID RESIDUES

The survey requested information on the amount and management of miscellaneous solid residues generated. These materials include broke not recovered internally; virgin fiber pulping rejects; secondary fiber pulping rejects; paper mill rejects; lime mud not recycled internally; lime slaker grit; green liquor dregs; solid waste from the wood yard not burned; raw water treatment residuals; and general mill refuse. Respondents were given the opportunity to report on any other miscellaneous residues they generated in 1995.

This section examines the generation rates overall for the miscellaneous solid residues, the rates for individual materials, and the ways in which the materials were managed.

4.1 Miscellaneous Solid Residues Generation Rates

One hundred seventy-seven mills reported generation of miscellaneous residues. Of those mills, 128 were single-category mills that could be used in calculating category-specific production-normalized generation rates (See Table B6, Appendix B). The median generation rate for all reporting mills was 116 dry pounds per ton of shipped product.

4.1.1 *Trends in Generation Rates*

There are no reliable data on generation of miscellaneous residues before 1988 so trends before that year cannot be examined.

The median generation rate reported for 1988 is 102 dry lb/ton (NCASI 1992)[1]. This would indicate that the overall median generation rate for miscellaneous residues increased by about 14% between 1988 and 1995. There is no statistical evidence that the two medians differ (Mann-Whitney test, $p=0.20$).

4.2 Miscellaneous Solid Residues Quantities

Estimation of quantities of these materials is problematic. The only practical approach with the information available is to use production-normalized generation rates with category-specific production rates. This approach works well for materials that are generated in the manufacturing process such that their quantities should be closely related to the type and quantity of product manufactured. Some residues, however, are not as closely linked to production. Examples are general mill refuse and wood yard residues. For these materials, category-by-category estimation based on production may not be accurate. This same problem exists for ash, but a reasonable alternative methodology based on fuel consumption is available in that case. For miscellaneous residues, no such alternative exists. Since the majority of the miscellaneous materials are closely linked to production, estimation based on production-normalized generation rates may not be greatly affected by those materials for which the linkage is less direct.

Some of the miscellaneous residues (e.g., grits and dregs) are commonly sent to the wastewater treatment facility where they are removed in the primary clarifier. This material then becomes part of the primary wastewater treatment residuals. The generation rates and quantities reported here have not been adjusted for this practice. The values reported refer to the total generation regardless of subsequent handling of the material.

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[1] NCASI (1992) stated the median as 60 dry pounds per ton. The figure given here is based on recalculation using the most current version of the 1988 data.

4.2.1 *Estimated Total Industry Quantity*

Table 7 presents the category-specific and industry total estimated quantities for all miscellaneous residues combined. The best available estimate of the quantity of miscellaneous residues generated by the U.S. pulp and paper industry in 1995 is 5.91 million dry tons.

Table 7. Estimated Quantity of All Miscellaneous Residues in 1995

Product - Fiber Category	Estimated Thousands of Dry Tons[a]
Bleached Container & Box - Bleached Kraft	398
Construction - Any Fiber	13.3
Corrugating Medium - Nondeinked	367
Corrugating Medium - Semi-chemical	222
Dissolving Pulp - Bleached Kraft or Sulfite	135
Market Pulp - Bleached Kraft or Sulfite	664
Newsprint - Deinked	132
Newsprint - Mechanical plus Deinked	305
Printing & Writing - Bleached Kraft	1,120
Printing & Writing - Mechanical plus Other	291
Printing & Writing - Purchased	344
Printing & Writing - Sulfite	162
Packaging & Industrial - Purchased	165
Recycled Container & Box - Nondeinked	376
Tissue & Toweling - Deinked	142
Tissue & Toweling - Nondeinked	21.9
Unbleached Container & Box - Unbleached Kraft	1,060
Total	5,910

[a]Rounded to three significant figures

4.2.2 *Trend in Quantity*

The quantity of miscellaneous residues reported for 1988 based on the revised median generation rate is 4.4 million dry tons. The 1995 estimate of 5.91 million tons is a 34% increase, twice the increase in production during the same period. Because of the high variability in the estimated generation rates for both surveys, the uncertainty in the percent increase is also high. Since the 1988 data do not specify the quantities of individual materials generated, it is difficult to investigate possible reasons for any increase.

4.2.3 *Quantities by Type of Residue*

For the first time, quantity information for individual miscellaneous residues was collected in the 1995 survey. This allows a unique depiction of relative amounts of these materials generated by the industry as presented in Figure 11.

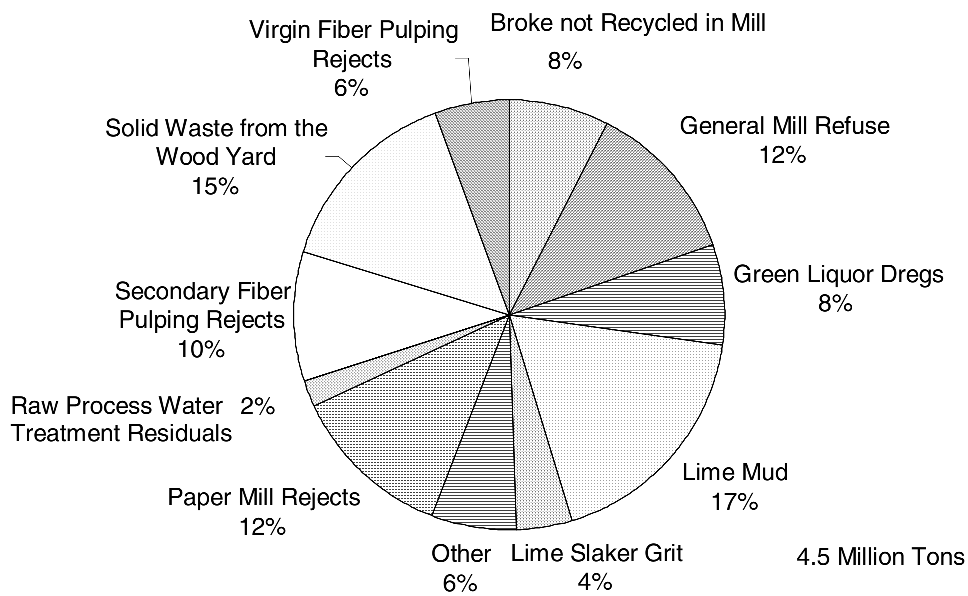

Figure 11. Miscellaneous Residues Generation by Type

The percentages depicted in the figure are based on dry weight. If the percentages were based on volumes rather than weights, it is clear that the denser materials (e.g., causticizing and wood yard residues) would represent smaller percentages and the lighter materials (e.g., broke, rejects) would be assigned higher percentages.

4.3 Miscellaneous Solid Residues Management Practices

About three fourths of the tonnage of miscellaneous solid residues reported in the survey had associated with it information on final disposition management practices. Table 8 presents information on the proportions of the individual materials managed in various ways.

The table illustrates that the nature of the residue dictates, in large part, how it is managed. Broke not recycled is relatively easy to use in a beneficial manner (mostly as by-products) whereas grits and dregs or secondary fiber pulping rejects presented more of a challenge so they tended to be landfilled. Over 50% of the wood yard residue was managed beneficially (this category intentionally excludes material that is burned). Much of the raw process water residuals was lagooned, but almost a quarter of those residuals were reportedly recycled or reused in-process. General mill refuse was primarily landfilled but 13% was beneficially used, much of that as a result of mill recycling programs. Most of the “Other“ category was landfilled, but the metals, cores, drums, and pallets were reused beneficially.

Table 8. Miscellaneous Residue Management for Final Disposition

Residue Type	Landfill/ Lagoon	Land Apply	Burn	Construction	Other Beneficial Use[a]	Recycle / Reuse
Broke not recycled in Mill	6.5%	NR	2.1%	NR	91%	NR
General Mill Refuse	83%	0.21%	3.2%	NR	12%	1.3%
Green Liquor Dregs	95%	3.0%	NR	0.33%	1.2%	NR
Lime Mud	70%	8.9%	NR	NR	21%	1.1%
Lime Slaker Grit	91%	5.5%	NR	0.03%	0.98%	2.8%
Paper Mill Rejects	38%	1.9%	6.2%	NR	19%	34%
Raw Process Water Treatment Residuals[b]	49%	2.7%	NR	NR	0.20%	22%
Secondary Fiber Pulping Rejects	68%	1.3%	30%	NR	0.40%	0.05%
Wood Yard Residue	47%	2.1%	NR	5.9%	44%	1.1%
Virgin Fiber Pulping Rejects	35%	NR	41%	NR	24%	NR
Other[c]	87%	NR	0.10%	11%	2.4%	0.21%
All Residues	63%	2.8%	6.0%	1.9%	24%	2.0%

NR = None Reported
[a] includes composting, use in by-products, or distribution to others for use as-is
[b] An additional 26% was discharged untreated to the receiving water.
[c] all other miscellaneous waste, including drums, cores, construction debris, etc.

Figure 12 depicts the management of miscellaneous residues overall using the data from the last line of Table 8. This makes it clear that the majority of these materials were landfilled. However, it is also clear that the industry made significant efforts to beneficially use miscellaneous residues.

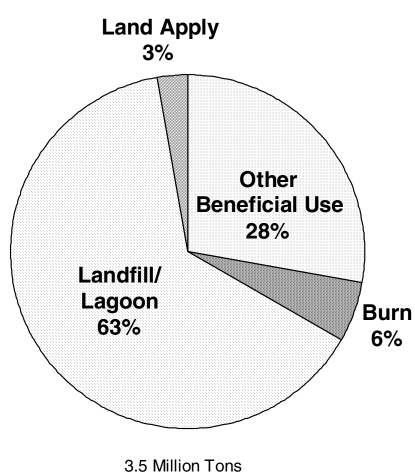

Figure 12. Management for Final Disposition of Miscellaneous Solid Wastes

4.3.1 *Trends in Management of Miscellaneous Residues*

Because the 1988 survey did not solicit quantity information on miscellaneous residues, direct comparisons with the 1995 data are difficult. A semi-quantitative comparison of the information in this report with information presented by NCASI (1992) indicates that any differences in management of miscellaneous residues are probably small. Land disposal predominates over the entire period. Patterns of management among the individual materials appear to be similar for both data sets.

5.0 TOTAL SOLID RESIDUES

Total solid residues refers to the combined quantities of wastewater treatment residuals, ash, and miscellaneous residues. Hazardous waste is not included in this calculation because most of the material reported by the industry is actually liquid rather than solid. While regulatory definitions refer to such materials as "solid waste," their inclusion in the total solid residues quantity would unduly distort that figure.

The available data allow calculation of this quantity in three semi-independent ways. One way is to project from category-specific production-normalized median generation rates as is done for wastewater treatment residuals and miscellaneous residues. The second way is to determine a total residue generation rate for all respondents which, when multiplied by the total production, will yield an estimate of total residues generated. Finally, the estimated totals presented previously for each component could simply be added together. The latter approach double counts small amounts of some materials that are normally sewered and therefore counted in wastewater treatment residuals. This effect is avoidable in the former two approaches because respondents were asked to indicate how much of each material was sewered. All three estimates are calculated and compared in this section.

5.1 Total Solid Residues Generation Rate

The median generation rate for total solid residues in 1995 was 270 lb/ton. In 1988, the median generation rate was 248 lb/ton. The difference is not statistically significant (Mann-Whitney Test, $p=0.24$).

Category-specific statistics for total solid residue generation rates are presented in Table B7, Appendix B.

5.2 Estimated Total Solid Residues Quantity

Table 9 presents the category-specific and overall total estimated quantities of total solid residues generated by the industry in 1995.

Multiplying the overall 1995 median generation rate of 270 lb/ton by the 1995 total production (including market pulp and construction grades) yields an estimated total solid residue quantity of 14.1 million dry tons. Adding together the previously reported estimated industry total quantities of wastewater treatment residuals (5.83 million tons), ash (2.81 million tons), and miscellaneous residues (5.91 million tons) yields an estimated total solid residue generation of 14.6 million dry tons in 1995.

Table 9. Category-by-Category Estimation of Total Solid Residues Quantity

Product - Fiber Category	Estimated Thousands of Dry Tons[a]
Bleached Container & Box - Bleached Kraft	1,080
Construction - Any Fiber	67.5
Corrugating Medium - Nondeinked	297
Corrugating Medium - Semi-chemical	590
Dissolving Pulp - Bleached Kraft or Sulfite	321
Market Pulp - Bleached Kraft or Sulfite	980
Newsprint - Deinked	465
Newsprint - Mechanical plus Deinked	768
Printing & Writing - Bleached Kraft	3,340
Printing & Writing - Mechanical plus Other	578
Printing & Writing - Purchased	486
Printing & Writing - Sulfite	267
Packaging & Industrial - Purchased	264
Recycled Container & Box - Nondeinked	666
Tissue & Toweling - Deinked	2,120
Tissue & Toweling - Nondeinked	105
Unbleached Container & Box - Unbleached Kraft	2,190
Total	14,600

[a]Rounded to three significant figures

Given the uncertainties in all these estimates, it is reasonable to conclude they are all essentially in agreement. This indicates that double counting due to materials being sewered is not a significant factor in calculating the estimates. In order to maintain mathematical consistency with the estimated quantities of the components of the total solid residue, the best estimate is taken as the sum of those figures, which also agrees with the category-by-category estimate. The best available estimate of the quantity of total solid residues generated by the U.S. pulp and paper industry in 1995 is 14.6 million dry tons.

Figure 13 shows the distribution of the total solid residues between wastewater treatment residuals, ash, and miscellaneous solid residues as reported by 183 respondents. Quantities of ash and miscellaneous residues are adjusted for sewering. Each material represents roughly a third of the total.

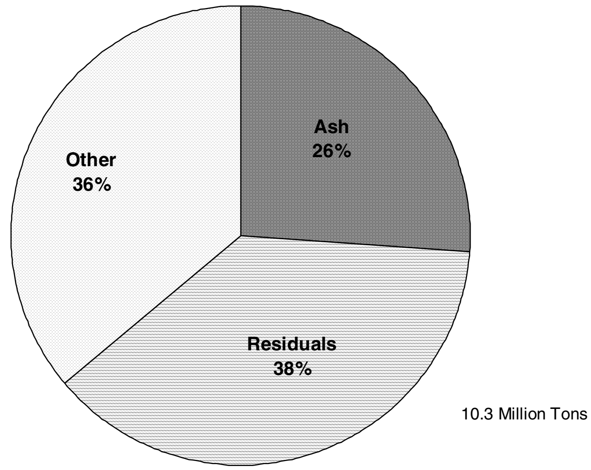

Figure 13. Composition of Total Solid Residues as Managed

5.2.1 *Trend in Total Solid Residue Quantity*

The estimated total solid residue quantity in 1988 based on adding together the components (as revised in this Bulletin) was 11.8 million dry tons (NCASI 1992). The 1995 estimate of 14.6 million tons represents a 24% increase over the 1988 estimate. While the estimation method precludes meaningful statistical comparison, it is noteworthy that the increase is only slightly more than the 17% increase in production. Moreover, all of the increase was due to wastewater treatment residuals and miscellaneous solid residues. There was no increase in ash.

As discussed previously, the increase in wastewater treatment residuals is probably due primarily to production increases and secondarily due to reduced quality of recovered fiber sources. Lack of detail in the 1988 data for miscellaneous residues precludes detailed exploration of the reasons for their increase, but at least some of it is very likely also related to the same factors. Production-related residues like causticizing wastes and broke would be expected to rise as production rises. Furnish-related residues like secondary fiber pulping rejects would be expected to rise as furnish quality decreases. Thus, the 24% increase in total solid residues is also probably due mainly to the production increase with some increase also caused by the use of lower grades of recovered fiber furnish.

6.0 LAND-BASED UNITS

The survey requested basic information (number, size) for a variety of land-based wastewater treatment and solid residue management units. More detailed information was requested on landfills. This section summarizes the responses received. No attempt is made to extrapolate reported values to industry totals because there is no reliable way to determine the degree of coverage of the industry these data represent.

6.1 Number and Size of Land-Based Units

Table 10 summarizes the data regarding the number and size (surface area) of the land-based units reported by 134 different respondents. Numbers of responses listed in the table are less than 134 because not all respondents reported each type of unit.

Table 10. Number and Size of Land-Based Units Reported

Type of Unit	No. of Units	Number of Response	Total Surface Area
Wastewater Treatment Basin	294	101	18,800
Active Landfill	129	112	4,730
Other Basins[a]	249	89	2,720
Total	672	134	26,300

[a] Includes spill ponds, liquor storage, lime mud storage, ash ponds, etc.

6.2 Landfills

Table 11 summarizes the responses to several questions about the size, age, remaining life, and costs associated with company-owned landfills.

Table 11. Parameters for Company-Owned Landfills

Parameter	Median	Mean	Standard Deviation	Minimum	Maximum	Number of Landfills
Permitted Acres	30.0	50.4	63.2	3	308	135
Percent Full	67.0	62.4	32.8	0	100	132
Age, yr.	13.0	15.1	11.5	0	65	128
Remaining Life, yr.	10.0	14.5	19.7	0	150	128
Cost to Use, $/cubic yard	$10	$16	$39	<$1	$400	107

The numbers of landfills vary within the table and in comparison to Table 10 because not all questions were answered for all landfills. Comments on the questionnaires indicated that not all respondents included the same cost components when estimating the use cost for their landfills. This is reflected in the high variability associated with the responses. Therefore, the cost figures should be considered only rough estimates. Use costs were not significantly correlated with landfill age ($r=0.17$, $p=0.09$), though the tendency was toward lower costs for older landfills.

About a third of respondents (34 of 121) indicated they were involved in efforts to permit more landfill space. These respondents expected the process to take a median time of 2.75 years (mean=3.7). The median estimated cost to use a new landfill was about $22/cubic yard (mean=$38/cubic yard).

6.3 Materials Sent to Company-Owned Landfills

Information is presented in previous sections on the amounts of various materials landfilled. Those totals included amounts sent to any landfill, including landfills operated by municipalities or private third parties. Figure 14 summarizes the responses indicating amounts of materials sent to company-owned landfills. The figure is based on aggregation of 4.6 million dry tons of materials reportedly sent to company-owned landfills by 120 respondents.

It is important to understand that Figure 14 cannot be used to infer the composition of a "typical" or "representative" company-owned landfill. A review of data on the specific contents of a limited number of landfills using detailed data obtained in the 1988 survey (NCASI 1992) indicates that differences between facilities in amount and type of production, power generation and energy recovery operations, regulatory requirements, and beneficial use opportunities, among other factors, yield wide variations in landfill characteristics with regard to design, type of materials contained, and relative quantities of each type of material present in any particular industry landfill.

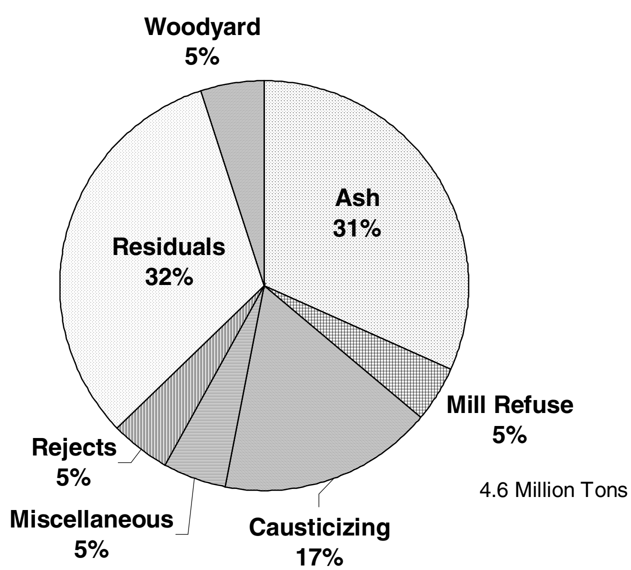

Figure 14. Materials Sent to Company-Owned Landfills Industry-Wide

7.0 GROUNDWATER MONITORING

About 88% of respondents who reported having active or inactive land-based units also reported operating a groundwater monitoring system on some kind of land-based unit. Table 12 summarizes the data regarding the coverage of land-based units by groundwater monitoring systems. The percentages are based on the number of units, not the number of respondents. Data from 1988, which were for active units only, are presented for purposes of identifying trends.

Table 12. Monitoring of Land-Based Units

	Landfill		WWT Basin		Other Basins[a]		Overall	
Survey Year	Active	All	Active	All	Active	All	Active	All
1995 (active and all)	93%	80%	48%	48%	35%	36%	53%	53%
1988 (active only)	67%	-	46%	-	24%	-	43%	-

[a] includes spill ponds, liquor storage, lime mud storage, ash ponds, etc.

Landfills were the main object of groundwater monitoring reported in both years, with over 90% of all active landfills monitored in 1995. Over half of all land-based units were monitored in 1995. Monitoring coverage of active units increased by 10 percentage points for all units between 1988 and 1995. Monitoring of active landfills increased by over 25 percentage points.

Of the respondents indicating operation of a groundwater monitoring system, 65% indicated the data collected were stored in an electronic database, 61% said the data were subjected to routine statistical analysis, and 55% said the data were subjected to routine graphical analysis (e.g., temporal or spatial trend plots).

8.0 SUMMARY AND CONCLUSIONS

NCASI collected solid residue generation and management data for 1995 from 285 U.S. pulp and paper facilities representing approximately 70% of that year's U.S. pulp and paper production. Facilities were organized into 17 product-fiber categories for reporting purposes. Procedures were used to extrapolate to non-responding facilities and to account for facilities that did not fit a single product-fiber category. Generation rates, quantity generated, and management methods were determined both category-by-category and overall for wastewater treatment residuals, ash, miscellaneous residues, and total solid residues. Table 13 summarizes the results.

Table 13. Summary of Generation Rates, Quantities, and Management of Solid Residues

			Management (% of dry weight)	
Solid Residue	Generation Rate dry lb/ton shipped product	Quantity (million dry tons)	Landfill/ Lagoon	Beneficial Use
Wastewater Treatment Residuals	87	5.83	51%	49%
Ash	NA *(See Sec. 3.1)*	2.81	72%	28%
Miscellaneous	116	5.91	63%	37%
Total Solid Residues	270	14.6	60%	40%

Wastewater treatment residuals, ash, and other solid residues each comprised roughly a third of the dry weight of all solid residues generated in 1995. Trends in generation rates were flat or slightly increasing. The quantity of ash generated was essentially unchanged from 1988. The quantity of wastewater treatment residuals was about 26% higher than in 1988, probably due to increased production and use of lower grade recovered fiber. The quantity of miscellaneous waste, which was reported differently in 1995, was apparently 34% higher than in 1988. Reasons for this increase are not readily apparent. The quantity of all solid residues was 24% higher in 1995 than in 1988, an increase not out of line with changes in production and furnish during the period.

Combination of wastewater treatment residuals prior to dewatering continued to be a common practice in 1995. Dewatering of residuals was dominated by belt filter and screw presses with some growth in the use of screw presses in the last decade. Dewatering of wet ash was still done mostly with gravity systems, either land-based or mechanical.

Land disposal was still the predominant management option used by the industry for solid residues in 1995, particularly for other than wastewater treatment residuals. However, the use of land disposal has been decreasing steadily for at least two decades as beneficial use (e.g., land application, burning, construction, recycling) has steadily increased.

Survey respondents reported management of almost 700 land-based units (wastewater treatment basins, other basins, and landfills), covering a total of approximately 26,000 acres. The median landfill covered 30 acres, was 13 years old with 10 years of life remaining, was two-thirds full, and cost $10 per cubic yard to use. All these characteristics, particularly the cost, exhibited large variability. Most of the facilities managing land-based units (88%) reported operation of one or more groundwater monitoring systems. Over half of all land-based units were monitored. Over 90% of active landfills were monitored. Monitoring increased between 1988 and 1995. About half of the groundwater monitoring data collected was routinely analyzed statistically or graphically.

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APPENDIX A

CATEGORIZATION AND EXTRAPOLATION

This appendix provides additional detail on how facilities were categorized and how quantities of some residues were extrapolated to produce estimates of total industry generation.

CATEGORIZATION

The 17 product-fiber categories (see Table A1) are based, in part, on categories used by the American Forest and Paper Association for reporting of industry production statistics. This was done to harmonize reporting of environmental statistics with reporting of production statistics. However, AF&PA statistics are based on product only. The fiber source for the product is not considered. Fiber source is, nevertheless, relevant in environmental statistical reporting because fiber source dictates process, which in turn can have a profound effect on environmental outcomes. Thus, the categories are composites of AF&PA production categories and a variety of fiber sources: bleached kraft, sulfite, mechanical, purchased, deinked, or nondeinked.

Generally speaking, a facility was put into a category if the nominal category final product and fiber source each accounted for 70% or more of the facility's products and fiber sources. However, in order to maximize the number of mills placed in single categories, some exceptions to the 70% criteria were made where it was deemed unlikely that such exceptions would seriously bias the environmental statistics being reported. For the Printing and Writing Papers - Sulfite category, the 70% criterion for fiber was waived because the norm for integrated mills producing sulfite pulp appears to be that pulp produced on-site represents less than 70% of the furnish. The Corrugating Medium - Semi-chemical category allows a combination of fibers comprised of semi-chemical plus fiber other than nondeinked recovered fiber, to total at least 70% of the fiber furnish. Unbleached Container and Box - Unbleached Kraft has a minimum fiber criterion of 60% rather than 70%, and unbleached kraft market pulp produced on-site is counted.

Some of the 17 product-fiber categories include more than one fiber source. Those linked with the conjunction "or" represent criteria where one or the other of the fiber types was at least 70% of the total furnish for a particular respondent. Those linked with the conjunction "plus" indicate that for some facilities in the category, the two fiber sources may have had to be added together to reach 70%, while other facilities in the category may have reached 70% with just the first fiber listed.

Facilities were categorized based either on the production information they provided in their survey response or on production information available elsewhere (e.g., Lockwood-Post's Directory). Of 184 respondents to the NCASI survey, 145 fit into one of the seventeen categories. The remainder were complex mills best represented by a combination of two or more categories. Of the 101 RPTA respondents, 82 fit single categories. Of the 310 facilities categorized using other information, 278 fit single categories. Thus, about 85 percent (505/595) of facilities were characterized as fitting into one of the 17 product-fiber categories. The remaining 90 mills were treated as "complex" facilities as discussed below.

EXTRAPOLATION AND ESTIMATION

Two complications required use of extrapolation and estimation procedures. First was the problem of non-responding facilities. Because survey responses only accounted for a fraction of the total U.S. industry, it was necessary to use a procedure to estimate the total industry generation of the various materials of interest. Second, because some facilities, responding and non-responding, were complex (did not fit a single category), some procedure was needed to allocate residue quantities reportedly generated at those facilities to the multiple product-fiber categories to which the facilities belonged.

Non-Responding Facilities

Had all production facilities in the U.S. responded to the survey, the estimated total 1995 generation of, for example, wastewater treatment residuals, would have been just the sum of the amount reported by respondents. Because all facilities did not respond, however, a method of accounting for non-response was necessary. The approach used was as follows:

1. For each of the 17 product-fiber categories, determine from survey responses for single-category facilities, a median production-normalized waste generation rate (e.g., dry lb/shipped ton of product). (Medians rather than means were used because most of the generation rates are from skewed, non-normal distributions.)
2. Determine from AF&PA production statistics, the total U.S. production of final products for each of the product-fiber categories. (Some of the categories had to be combined for this step because the AF&PA production statistics were not sufficiently detailed with regard to fiber source to support a determination for every category.)
3. Calculate for each category or combination of categories, the difference between production reported by respondents and the total reported by AF&PA.
4. Determine from other sources (e.g., Lockwood-Post's Directory) the production (or production capacity) for non-responding mills in each category or combination thereof. Calculate a correction factor as the ratio of the production difference determined in Step 3 to the production determined in this step.
5. Allocate production from non-responding mills into the 17 product-fiber categories.
6. Multiply each category median generation rate (Step 1) by the category non-respondent production (Step 5) and by the category correction factor (Step 4) to give an estimated quantity of waste material generated by non-respondents in each category.
7. Add quantities reported by respondents in each category to quantities estimated for non-respondents in Step 6. Sum over categories to yield an estimate for all U.S. facilities.

Complex Facilities

When a facility did not meet the criteria to be placed into a single category, it was considered a complex facility. Using either survey-reported or other available production data, it was possible to determine what fraction of production at such facilities fit into each established category. For survey respondents, this information was used in conjunction with the established category generation rates to allocate the appropriate portion of each complex facility's reported quantity of residue material to the various product-fiber categories. Details of this allocation procedure are given below. For non-respondents, production was just assigned to the appropriate category to be included in the estimation calculation (Step 5 above).

Allocation of waste materials to different product-fiber categories for respondents that did not fit a single category was done using a weighting formula that took into account the fraction of production in each category and the differing median generation rates for each category. Equation A1 is the formula used.

$$Q_i = \left[\frac{F_i M_i}{\sum_{1}^{n} F_i M_i} \right] Q_T \qquad \text{Equation A1}$$

Where: Q_i = the quantity of residue (e.g., wastewater treatment residuals) allocated to the i^{th} product-fiber category

F_i = the fraction of production at the facility in the i^{th} product-fiber category.

M_i = the i^{th} product-fiber category median production-normalized generation rate for the residue in question.

For example, consider a hypothetical complex mill that reported generation of 2000 dry tons of wastewater treatment residuals in 1995. Tissue and Toweling - Deinked accounted for 60 percent of the mill's production and Newsprint – Mechanical plus Deinked accounted for 40 percent. How much of the 2000 tons of residuals should be assigned to each product-fiber category?

The median residuals generation rates for the two categories are 867 lb/ton and 204 lb/ton, respectively. The quantity of residuals assigned to Tissue and Toweling - Deinked is:

$$Q_{tiss} = \left[\frac{0.6(867)}{0.6(867) + 0.4(204)} \right] 2000 = 1729 \, tons$$

The remainder, 271 tons, is assigned to Newsprint – Mechanical plus Deinked.

Comprehensive Example: Estimation of Wastewater Treatment Residuals Quantity

Table A1 illustrates the methodology for estimation of the quantity of wastewater treatment residuals generated in 1995. Note that categories involving corrugating medium (CM), newsprint (NEWS), printing and writing grades (P&W), and tissue were subjected to some consolidation for purposes of assignment of production to non-respondents. This is because AF&PA statistics are based on product only and make no distinction based on fiber source. Note also that AF&PA's reported production figure is larger than the commonly published total for paper and paperboard. This is because the commonly published figures usually omit market pulp, dissolving grades, and construction grades.

The procedure described here was used to estimate national totals for wastewater treatment residuals, miscellaneous solid residues, and total solid residues. The estimation procedure for ash is described in the text of this technical bulletin.

Table A1. Estimation of Total Wastewater Treatment Residuals Generation

Product –Fiber Category	Survey Residuals Median Generation Rate (lb/ton)	AF&PA Reported Production (tons)	Survey Reported Production (tons)	Non-Respondent Published Production (tons)	Non-Respondent Allocated Production (tons)	CF	Survey Reported Residuals (tons)	Estimated Non-Respondent Residuals (tons)	Estimated Total Residuals (tons)
Bleached Container & Box - Bleached Kraft	68.69	5,304,100	3,599,352	2,492,696	2,707,946	0.68	290,239	63,605	353,844
Construction – Any Fiber[a]	5.4	4,716,724	244,068	4,472,656	4,472,656	1.00	944	12,076	13,020
Corrugating Medium – Nondeinked	32.71	8,985,800	5,287,180	4,883,636	2,506,826	0.76	19,999	31,051	51,050
Corrugating Medium – Semi-chemical	81.6				2,376,810	0.76	127,804	73,443	201,247
Dissolving Pulp – Bleached Kraft or Sulfite[a]	135.6	1,327,000	1,028,977	529,966	529,966	0.56	101,790	20,206	121,996
Market Pulp – Bleached Kraft or Sulfite[a]	41.88	9,357,000	8,558,692	2,241,214	2,164,214	0.36	148,932	16,142	165,074
Newsprint – Deinked	537.44	7,001,800	5,392,305	3,827,723	140,000	0.42	328,807	15,819	344,626
Newsprint – Mechanical plus Deinked	204.11				3,687,723	0.42	303,388	158,249	461,637
Printing & Writing – Bleached Kraft	125.56	25,405,200	20,084,455	6,647,352	3,296,527	0.80	913,942	165,654	1,079,596
Printing & Writing – Mechanical plus Other	121.21				786,950	0.80	178,590	38,175	216,765
Printing & Writing – Purchased	88.09				3,597,788	0.80	149,478	126,840	276,318
Printing & Writing – Sulfite	160.17				182,250	0.80	130,574	11,683	142,257
Packaging & Industrial – Purchased	52.85	4,263,400	1,698,840	1,289,289	804,979	1.99	22,632	42,312	64,943
Recycled Container & Box – Nondeinked	49.67	9,515,300	6,674,358	3,851,823	3,942,493	0.74	157,674	72,216	229,890
Tissue & Toweling – Deinked	867.4	6,210,300	2,719,239	3,524,892	2,086,405	0.99	642,028	896,189	1,538,218
Tissue & Toweling – Nondeinked	178.68				299,324	0.99	13,631	26,485	40,116
Unbleached Container & Box – Unbleached Kraft	36.33	22,835,100	14,775,943	7,467,280	7,645,670	1.08	380,054	149,892	529,946
Totals:	--	104,921,724	70,063,410	41,228,527	41,228,527	--	3,910,507	1,920,037	5,830,543

[a] usually excluded from published production statistics for paper and paperboard

APPENDIX B

CATEGORY-SPECIFIC DATA

Wastewater Treatment Residuals

Overall Generation Rates

Table B1. Wastewater Treatment Residuals Generation Rates
(dry lb. per short ton of shipped product)

Product-Fiber Category	Median	Mean	Std. Dev.	Min.	Max.	n
Bleached Container & Box - Bleached Kraft	68.7	81.2	61.3	19.2	211	8
Construction – Any Fiber	5.40	20.4	28.4	2.74	53.1	3
Corrugating Medium – Nondeinked	32.7	45.4	53.3	0.326	132	5
Corrugating Medium – Semi-chemical	81.6	132	110	68.6	297	4
Dissolving Pulp – Bleached Kraft or Sulfite	136	159	128	48.3	315	4
Market Pulp – Bleached Kraft or Sulfite	41.9	70.4	82.7	14.5	251	7
Newsprint – Deinked	537	524	251	229	793	4
Newsprint – Mechanical plus Deinked	204	197	64.2	102	283	5
Printing & Writing – Bleached Kraft	126	138	72.1	20.5	325	22
Printing & Writing – Mechanical plus Other	121	140	59.1	85.1	234	8
Printing & Writing – Purchased	88.1	130	111	22.1	358	14
Printing & Writing – Sulfite	160	172	89.1	76.4	285	6
Packaging & Industrial – Purchased	52.9	178	260	41.2	791	8
Recycled Container & Box – Nondeinked	49.7	88.1	114	1.11	480	29
Tissue & Toweling – Deinked	867	823	217	450	994	5
Tissue & Toweling – Nondeinked	179	194	86.9	106	313	4
Unbleached Container & Box – Unbleached Kraft	36.3	56.0	56.0	3.81	180	13
All respondents regardless of category[a]	86.9	146	178	0.326	994	196

[a] All reporting mills, including complex mills which do not fit a single category. Not all respondents provided useable information.

1988 and 1995 Generation Rates

NCASI last reported treatment residuals generation rates based on data for 1988 (NCASI 1992). The categorization scheme used at that time was different than the one described above. The 1988 production categories were based on EPA effluent guidelines regulatory subcategories. The correspondence to the AF&PA categories for statistical reporting is not perfect, but 13 product/fiber categories are sufficiently comparable between the two surveys to support a valid characterization of trends. Table B2 presents a comparison of median residuals generation rates between 1988 and 1995.

Because the sample sizes for most categories are rather small, the category-specific data in Table B2 should be used with some caution. It is likely that the direction of the change is more reliable than the magnitude of the change.

Table B2. Comparison of 1988 and 1995 Median Wastewater Treatment Residuals Generation Rates (dry pounds per short shipped ton)

	1988		1995	
Product/Fiber Category	n	lb/ton	n	lb/ton
Bleached Container & Box - Bleached Kraft	5	115	8	68.7
Corrugating Medium – Semi-chemical	5	82.8	4	81.6
Dissolving Pulp – Sulfite	3	131	4	136
Market Pulp - Bleached Kraft	5	127	7	41.9
Newsprint – Mechanical	3	86.7	5	204
Printing & Writing – Bleached Kraft	17	160	22	126
Printing & Writing – Mechanical	5	101	8	121
Printing & Writing – Purchased	10	51.7	14	88.1
Printing & Writing – Sulfite	4	210	6	160
Packaging & Industrial - Purchased	7	66.3	8	52.9
Recycled Container & Box - Nondeinked	3	52	29	49.7
Tissue & Toweling – Deinked	7	777	5	867
Unbleached Container & Box - Unbleached Kraft	17	37.5	13	36.3
All survey respondents regardless of category	135	96	196	87

Generation Rates of Primary and Secondary Residuals

The generation rates disregard whether the primary (Table B3) or secondary (Table B4) residuals are ultimately combined. However, the RPTA data do not allow some tonnage reported as combined residuals or residuals plus secondary fiber pulping rejects to be separated into primary and secondary contributions alone. Therefore, RPTA information was used only when primary or secondary tonnage could be discerned from the combined tonnage. As expected, there are fewer mills reporting secondary residuals (78 respondents) than primary (189). Of the reported wastewater treatment residuals, 85% are primary while secondary accounts for only 8% with the remainder being dredged (5%) and unidentifiable residuals reported by RPTA respondents (2%).

Table B3. Primary Treatment Residuals Generation Rates
(dry pounds per ton of shipped product)

Product/Fiber Category	Median	Mean	Standard Deviation	Minimum	Maximum	n
Bleached Container & Box – Bleached Kraft	68.7	81.2	61.3	19.2	211	8
Construction – Any Fiber	5.40	20.4	28.4	2.74	53.1	3
Corrugating Medium – Nondeinked	37.2	51.7	58.4	0.329	132	4
Corrugating Medium – Semi-chemical	76.7	115	107	34.3	273	4
Dissolving Pulp– Bleached Kraft or Sulfite	115	124	89.4	48.0	220	4
Market Pulp – Bleached Kraft or Sulfite	41.9	56.9	56.2	14.5	1766	7
Newsprint – Deinked	533	507	229	229	734	4
Newsprint – Mechanical plus Deinked	169	181	61.0	102	268	5
Printing & Writing – Bleached Kraft	109	122	69.5	20.5	325	22
Printing & Writing – Mechanical plus Other	119	124	54.5	66.6	223	8
Printing & Writing – Purchased	87.3	121	97.1	22.1	315	14
Printing & Writing – Sulfite	150	148	57.7	84.1	234	5
Packaging & Industrial – Purchased	47.3	174	262	24.2	791	8
Recycled Container & Box – Nondeinked	39.3	81.7	113	1.11	480	23
Tissue & Toweling – Deinked	854	745	294	225	923	5
Tissue & Toweling – Nondeinked	194	212	92.3	131	313	3
Unbleached Container & Box – Unbleached Kraft	36.3	50.6	48.8	3.81	180	13

Table B4. Secondary Treatment Residuals Generation Rates
(dry pounds per ton of shipped product)

Product/Fiber Category	Median	Mean	Standard Deviation	Minimum	Maximum	n
Bleached Container & Box – Bleached Kraft	NA	NA	NA	NA	NA	0
Construction – Any Fiber	NA	NA	NA	NA	NA	0
Corrugating Medium – Nondeinked	10.2	10.2	5.88	6.01	14.3	2
Corrugating Medium – Semi-chemical	24.7	23.0	12.3	9.91	34.3	3
Dissolving Pulp – Bleached Kraft or Sulfite	29.0	45.8	43.9	12.8	95.6	3
Market Pulp – Bleached Kraft or Sulfite	47.2	47.2	39.1	19.6	74.8	2
Newsprint – Deinked	33.5	33.5	35.5	8.40	58.5	2
Newsprint – Mechanical plus Deinked	28.4	26.6	11.4	14.4	37.0	3
Printing & Writing – Bleached Kraft	29.1	31.3	12.1	15.1	52.9	11
Printing & Writing – Mechanical plus Other	12.2	17.5	11.8	3.74	34.9	7
Printing & Writing – Purchased	20.1	40.3	49.0	4.68	96.2	3
Printing & Writing – Sulfite	35.8	57.9	39.9	26.8	120	5
Packaging & Industrial – Purchased	14.1	14.1	4.16	11.2	17.1	2
Recycle Container & Box – Nondeinked	11.8	19.6	22.4	3.04	68.3	7
Tissue & Toweling – Deinked	33.4	78.1	86.9	13.1	225	5
Tissue & Toweling – Nondeinked	32.6	32.6	NA	32.6	32.6	1
Unbleached Container & Box – Unbleached Kraft	9.98	23.5	30.6	2.04	58.5	3

Management for Final Disposition

Table B5 presents the distribution of residuals between the various final disposition management options for each of the 17 product-fiber categories. Residuals from complex mills were allocated between the categories based on the amount of production in each category and the median residuals generation rate for each category. In this way, every ton of residuals reported is accounted for in the table.

Table B5. Wastewater Treatment Residuals Final Disposition Management by Product-Fiber Category

Product/Fiber Category	Landfill	Lagoon	Land Apply	Burn	Other Beneficial Use	Recycle
Bleached Container & Box – Bleached Kraft	12.9%	32.8%	14.8%	30.2%	2.42%	6.88%
Construction – Any Fiber	89.4%	NR	5.30%	NR	NR	5.30%
Corrugating Medium – Nondeinked	55.5%	NR	10.2%	11.6%	0.095%	22.6%
Corrugating Medium – Semi-chemical	20.8%	0.239%	24.7%	31.7%	2.37%	20.3%
Dissolving Pulp – Bleached Kraft or Sulfite	36.7%	11.3%	5.83%	46.1%	NR	NR
Market Pulp – Bleached Kraft or Sulfite	37.6%	10.6%	24.8%	24.9%	1.09%	1.02%
Newsprint – Deinked	15.1%	1.46%	10.7%	53.1%	18.7%	0.946%
Newsprint – Mechanical plus Deinked	20.4%	12.3%	3.47%	60.4%	3.47%	NR
Packaging & Industrial – Purchased	30.9%	NR	5.38%	6.33%	46.8%	10.6%
Printing & Writing – Bleached Kraft	49.9%	5.28%	15.8%	22.2%	5.70%	1.12%
Printing & Writing – Mechanical plus Other	54.6%	NR	18.8%	26.3%	0.370%	NR
Printing & Writing – Purchased	62.3%	0.502%	19.3%	3.51%	8.34%	6.04%
Printing & Writing – Sulfite	71.6%	NR	2.53%	21.9%	3.97%	NR
Recycled Container & Box – Nondeinked	45.4%	1.67%	0.501%	0.780%	3.67%	48.0%
Tissue & Toweling – Deinked	81.3%	0.570%	9.16%	NR	5.34%	3.62%
Tissue & Toweling – Nondeinked	40.1%	NR	8.98%	1.01%	49.9%	NR
Unbleached Container & Box – Unbleached Kraft	29.5%	9.63%	9.33%	43.1%	0.407%	8.08%

NR = None Reported

Miscellaneous Solid Residues

Table B6 presents category-specific statistics for generation rates. The last line of the table presents results for all mills whether or not they fit a single category.

Table B6. Miscellaneous Solid Residues Median Generation Rates (dry lb/ton)

Product/Fiber Category	Median	Mean	Standard Deviation	Minimum	Maximum	n
Bleached Container & Box – Bleached Kraft	117	148	126	1.80	438	8
Construction – Any Fiber	5.60	5.60	2.90	3.60	7.70	2
Corrugating Medium – Nondeinked	190	190	59.8	148	232	2
Corrugating Medium – Semi-chemical	106	131	82.9	74.2	276	5
Dissolving Pulp – Bleached Kraft or Sulfite	199	175	63.5	81.8	222	4
Market Pulp – Bleached Kraft or Sulfite	181	179	177	25.3	531	7
Newsprint – Deinked	195	296	341	29.0	766	4
Newsprint – Mechanical plus Deinked	112	117	128	0.550	322	5
Printing & Writing – Bleached Kraft	135	184	136	46.7	573	22
Printing & Writing – Mechanical plus Other	160	169	124	29.5	401	8
Printing & Writing – Purchased	112	154	185	11.0	805	17
Printing & Writing – Sulfite	187	222	169	37.5	500	5
Packaging & Industrial – Purchased	138	165	118	22.3	383	8
Recycle Container & Box – Nondeinked	74.5	82.6	55.9	25.7	169	6
Tissue & Toweling – Deinked	79.2	164	132	58.7	346	5
Tissue & Toweling – Nondeinked	89.4	128	121	31.3	263	3
Unbleached Container & Box – Unbl. Kraft	84.7	103	78.1	19.9	334	17
All Respondents Regardless of Category[a]	116	154	141	0.550	805	177

[a] includes all reporting mills, including complex mills which do not fit a single category

Total Solid Residues

Production-normalized generation rates were determined for 134 single-category mills from the NCASI survey. RPTA survey data were excluded because that survey did not solicit information on all the residues (e.g., ash, most of the miscellaneous residues). The calculated generation rates were adjusted to account for reported amounts sewered. Table B7 summarizes the generation rates obtained for each product-fiber category as well as the rate for all respondents regardless of category.

Table B7. Total Solid Residue Generation Rates (dry lb. per short ton of shipped product)

Product/Fiber Category	Median	Mean	Standard Deviation	Minimum	Maximum	n
Bleached Container & Box – Bleached Kraft	318	314	161	20.9	540	8
Construction – Any Fiber	28.6	28.6	21.9	13.2	44.1	2
Corrugating Medium – Nondeinked	154	152	62.9	88.7	214	3
Corrugating Medium – Semi-chemical	281	314	149	148	525	5
Dissolving Pulp – Bleached Kraft or Sulfite	473	422	193	146	597	4
Market Pulp – Bleached Kraft or Sulfite	267	229	188	28	570	8
Newsprint – Deinked	685	665	306	335	955	4
Newsprint – Mechanical plus Deinked	281	333	157	141	533	5
Printing & Writing – Bleached Kraft	404	429	220	120	1,050	22
Printing & Writing – Mechanical plus Other	318	322	123	132	570	9
Printing & Writing – Purchased	159	267	235	25.6	857	18
Printing & Writing – Sulfite	309	363	231	172	793	6
Packaging & Industrial – Purchased	221	311	253	110	938	9
Recycled Container & Box – Nondeinked	132	149	124	25.7	361	6
Tissue & Toweling – Deinked	1,180	1,430	622	796	2,170	5
Tissue & Toweling – Nondeinked	430	391	124	253	491	3
Unbleached Container & Box – Unbleached Kraft	176	179	89.9	53.0	346	17
All respondents regardless of category[a]	270	338	294	2.59	2,170	18 3

[a] All reporting mills, including complex mills which do not fit a single category