Paper recycling in Australia and New Zealand

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Though deinking is not widely practiced in Australia and New Zealand at the moment, the subject is receiving a great deal of attention.

Paper recycling is unusual among the technologies of the pulp and paper industry in that its practice is perceived to be both economically and environmentally beneficial.

The incentive for recycling appears to be related in an inverse way to the availability of virgin fiber resources, although various other factors are involved. When forest area per person is plotted against wastepaper utilization rate for a number of developed countries, a smooth curve is obtained, with Japan at one extreme (high utilization rate, low forest area) and Canada at the other *(1)*.

In 1987–88 the recovery (or collection) rate (the amount of recyclable fiber collected expressed as a percentage of the total consumption of paper and paperboard) was 30% for Australia *(2)*, and the utilization rate (the amount of recovered fiber used in the manufacture of paper, expressed as a percentage of the total fiber used) was 36%, the difference being attributable to imports. A very recent estimate *(1)* of the utilization rate for 1990–91 is much higher, 44.6%, a respectable figure by world standards, but still well below some countries deficient in forest resources. The 1987–88 figure of 68% for packaging and industrial papers *(2)* is in line with Western Europe and Japan, although much below West Germany (prereunification). The figure of 6% for printing and writing papers is similar to the figure for the United States. The utilization rate for newsprint manufactured in Australia is at present zero, compared with 50% in West Germany, 25–30% in Western Europe as a whole, 20–25% in the United States, and 45–50% in Japan. For tissues, the rate is still very low in Australia, compared with 25% in West Germany, 40% in Western Europe, and 30% in the United States *(2)*.

An examination of various scenarios involving the increased use of wastepaper in Australia *(3)* led to the conclusion that a structure involving 50% recycled and 50% virgin fiber represents the most desirable goal to be achieved to satisfy and balance conservation requirements and development needs. It is estimated *(1)* that the utilization rate will exceed this goal and reach 54% by 1995.

I. Worldwide use of recycled fiber

			Printing and Writing		
	Newsprint	*Tissue*	*Total*	*Mechanical*	*WF**
No. of paper machines	355	939	2088	382	1706
Capacity (metric tons/year)	37.4	14.1	71	23	48
No. of machines using recycled fiber	106	619	c.405	c.64	c.341
Capacity (metric tons/year)	12	8.1	9.2	2.3	6.9
Reference	*(4)*		*(5)*		*(6)*

* WF = woodfree

Recycling and deinking: a chronology

Historically, recycling has been an important part of papermaking in Australia since the industry was established in the middle of the nineteenth century in Victoria and New South Wales. The first pulp mills, based on the indigenous eucalypt resource, were not commissioned until the late 1930s and early 1940s. Pulp mills were not built in New Zealand until after World War II, when the radiata pine plantations had developed sufficiently to sustain a large industry.

Hollander beaters were used initially by Australian PaperManufacturers (APM) for dispersing recycled fiber, and hydropulpers were introduced after the war. The Smorgon Group, originally a meat-processing, family company based in Melbourne, entered the packaging materials field in the late 1950s in competition with APM, and used considerable quantities of recycled fiber. They have recently withdrawn from the paper industry. The Pratt Group, based on Visy Board, a fiberboard container manufacturer, vertically integrated their operations and have been active in manufacturing packaging materials from recycled fiber, particularly in the 1980s.

APM makes packaging materials from furnishes containing large amounts of recycled fiber at five paper mills at Fairfield, Vic.; Botany, NSW; Petrie, Qld.; Spearwood, W.A.; and Broadford, Vic. The Pratt Group (Visy Paper) uses a furnish consisting entirely of recycled paper to make packag-

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II. A sampling of manufacturers of flotation cells and washers

Flotation
Lamort Flotation Cell—The Verticel
Voith Flotation Cell
Beloit-Jones PDM Flotation Cell (pressurized deinking module)
Sulzer-Escher Wyss CF Cell (compact flotation)
Black Clawson Deinking Cell
IIM-BC Flotator (ledger to tissue)
Ultra-TF Flotation Cell (old newsprint)
Swemac—Hellberg Cell
Kamyr's Gas-sparged Cyclone
Washing (11)
Sulzer-Escher Wyss Vario Split Washer
Black Clawson Double-nip Thickener

III. Washing versus flotation *(11)*

	Flotation	*Washing*
Yield loss	5–10%	15–20%
Fillers and fines	Retained	Removed
Ink removed	Conc. sludge	Very dilute
Waste water	Some *in situ* treatment	Must be done externally
Chemical costs	Slightly lower	. . .
Capital costs	. . .	Somewhat lower
Pulp quality	Higher opacity	Higher strength

ing materials at its paper mills at Warwick Farm, N.S.W.; Reservoir, Vic.; Smithfield, N.S.W.; and Coolaroo, Vic., which opened in 1980, 1983, 1986, and 1989, respectively.

A small tissue mill near Perth, AusTissue at Canning Vale, W.A., uses recycled paper in tissues, and the Bowater mill at Box Hill, Vic., uses a proportion of recycled fiber in its furnish *(2)*.

Recycled fiber is deinked and used for fine papers at APPM's mill at Shoalhaven, N.S.W. APM now makes writing and printing papers from recycled fiber at Fairfield, but without deinking.

The use of wastepaper in Australia was 588,000 metric tons in 1985–86, and it has increased to an estimated 900,000 metric tons in 1990–91. Over that period, wastepaper exports have increased steeply, from 5000 metric tons in 1985–86 to 95,000 metric tons in 1990–91 *(2)*. The 1990–91 estimates include about 500,000 metric tons used by APM, about 300,000 metric tons by Visy Paper and 22,000 metric tons by APPM.

Deinking is not widely practiced in Australia at the moment. The only plant was installed at the Shoalhaven mill in 1981, based on the Swemac flotation cell *(1)*. The wastepaper is collected from offices, being mainly printing and writing grades with a high content of chemical pulp, and the deinked pulp is used for fine and specialty papers. Australia has been slow to incorporate deinked stock in its newsprint furnishes, but this situation is now being redressed. Further deinking plants are planned by Australian Newsprint mills, at its mill at Albury, N.S.W., and by Visy Paper at its mill at Coolaroo, near Melbourne. The Albury mill makes newsprint from radiata pine thermomechanical pulp (TMP), and the use of recycled paper will represent a very large saving in electrical energy costs per metric ton of newsprint. Two other companies in Australia are giving consideration to the installation of deinking facilities.

In New Zealand, the main wastepaper recycling plant is at NZFP Pulp & Paper's mill at Te Papapa, near Auckland, where the fiber is used in the manufacture of corrugating medium (output 34,000 metric tons in 1988). The company's board mill at Whakatane also uses some recycled fiber, together with pine pulp produced on-site. New Zealand has no deinking plant, but interest in this technology appears to be growing.

The wide interest in deinking in Australia at present was reflected at the recent Jaakko Pöyry Deinking Conference, held in Melbourne in conjunction with Appita on Oct. 8–9, 1991. The conference attracted strong support with an attendance of some 150, and had to be moved to the Grand Ballroom of the Radisson President Hotel.

The world deinking scene

Worldwide there are 416 existing deinking lines, at 321 mills, with a total capacity of 13.5 million metric tons, of which newsprint manufacture comprises 43%, tissue 24%, printing and writing 14%, cartonboards 8%, and other products 11% *(4)*.

The use of recycled fiber in newsprint, tissue, and printing and writing grades is summarized in **Table I**, compiled from the references shown. Regional differences are pronounced, e.g., tissue mills account for 39% of deinking capacity in North America, newsprint for 34% (which will probably increase rapidly), and woodfree paper 15%, whereas in Japan newsprint accounts for 60% of capacity and tissue only 5%. In Western Europe, newsprint dominates deinking capacity, followed by tissue.

In newsprint manufacture, the waste material consists of old newspapers and magazines. In North America, pure newsprint waste has sometimes been used; in Western Europe, the proportion of newspapers to magazines is 60–70/40–30; in Germany, it is 50/50; and, in Japan, it is only 10–15/90–85. Magazine waste contains more chemical pulp, normally has higher brightness and pulp strength, shows a smaller aging effect than old newspapers, and the higher filler content tends to improve printing. On the other hand, the higher ash content may sometimes give rise to dusting problems, particularly with long runs in offset, and varying ash content between

IV. Some equipment suppliers for various unit operations

High-consistency cleaning and screening *(6, 7)*— Lamort, Aikawwa, Voith, Finckh

Low-consistency screening and cleaning *(6, 7, 12)*—Voith, Beloit, Black Clawson, Lamort

Thickening to 10% *(7)*Disc filters: Kufferath-Akse, Ahlstrom, Hedemora/Celleco, Voith

Thickening to 30% plus – Screw presses or wire presses: Andritz, Hedemora,Thune/Kvaerner-Eureka, Voith, Celleco, Bellmer

Dispersion *(12)* – Single-shaft and disc disintegrators: Voith

White water flotation *(5)*—Flootek, Krofta, Escher Wyss Purgomat

Sludge thickening *(13)* –Belt presses: Andritz, Bellmer, Eimco, Dorr Oliver. Centrifuges: Alfa-Laval, Dorr Oliver. Filter presses: Eimco, Dorr Oliver, Larox. Screw presses: Krima, FKC, Thune

Reject handling *(12)*—Voith

V. Mechanisms of ink release

Group	*Paper*	*Vehicle*	*Ink location*	*Ink removal*	*Specks*
1	Uncoated	Absorbed	Fiber	Flotation, washing	None
2	Uncoated	Solidified	Fiber	Flotation efficient	Limited
3	Coated	Solidified	Coating	–	Significant
4	Coated	Heat used	Fiber & Coating	–	Important

reels can be a problem. Furthermore, part of the fillers may be washed out during deinking, decreasing yield, and stiffness and bulk may also be decreased by the residual filler content *(4)*.

In tissue manufacture, heavily printed grades with a high content of mechanical pulp, and recycled fiber consisting of mainly unbleached sulfate pulp are commonly used. In North America, woodfree printing and writing papers are the dominant furnish components, the requirement for softness being higher than in Europe. In Japan, this grade of waste is also used for quality and strength *(5)*.

For the manufacture of printing and writing papers, the recycled waste comprises printed grades containing mainly mechanical pulp and woodfree printing and writing papers. Once again, practice varies greatly between regions. In North America, the high-grade woodfree papers are almost exclusively used, whereas in Japan, old newspapers and magazines and telephone directories are used exclusively to replace mechnical pulp. Old newspapers make up a greater proportion of the furnish than in Western Europe, where a 50/50 mix of newspapers and magazines is often used *(6)*.

The capacity of machines using recycled fiber to make newsprint is 32% of the total newsprint capacity (Table I). In North America, the corresponding figure is only 12%, compared with 93% in EEC countries and 84% in Japan. In Australia, it is zero at present, but plans to raise it substantially are advanced.

Available deinking technologies

Deinking consists essentially of separating the recyclable material into individual fibers, and then removing the contaminants *(7)*. A typical deinking system consists of a pulper, a high-density cleaner, coarse screens, deinking equipment, low-consistency cleaners, fine screens, light reject cleaners, a disc filter, a dewatering press, and a disperser. The equipment required depends on the nature of the recyclable material and the paper grade to be made. Fiber separation is effected in the first step, the pulper, and the rest of the plant is for contaminant removal.

Wastepaper pulping is a relatively simple process, being achieved by supplying water, heat, chemicals, and mechanical energy (stirring). The main aims of repulping are to break down the wastepaper into discrete fibers and to separate the ink from the fibers *(7)*. The stock concentration may range from 5% to 20%, but high stock concentration (about 15%) is now the accepted technology, offering several advantages over low-consistency pulping. High friction forces give thorough defibration, the pulping action is gentle enough not to chop contaminants into small fragments and, hence, impede their subsequent removal, and there is a saving in heat *(6)*. Temperatures above 50°C and high alkalinity are beneficial *(8)*, although for some wet-strength paper grades acid conditions are preferred. In high-consistency batch pulping, the residence time is usually 11–15 minutes.

After the pulper, the stock is diluted to 4–5% and pumped to a dump tank where further chemical reaction may take place to separate ink from fiber. Separation of fibers may also be enhanced by further rupture of interfiber hydrogen bonds and fiber swelling, with an improvement in the papermaking properties of the fibers, which are, in effect, reconditioned.

Drum pulpers provide continuous high-consistency pulping, up to 20% stock concentration, with dilution to 4–5% in a subsequent screening zone *(7)*, where the fibers are washed through holes in the drum into a stock tank, and contaminants emerge from the end of the drum. The residence time is about 20 minutes. Ahlstrom and Finckh manufacture drum pulpers of somewhat different design.

The efficiency of various unit operations in the process of contaminant removal—washing, flotation, cleaning and screening—depends largely on particle size, each having its maximum efficiency at a different size value *(9)*. Washing is efficient for very fine particles, the flotation process for somewhat coarser particles, cleaning for particles which are coarser still, and screening is most effective for the very coarse contaminants. Hence a combination of processes is required, the exact combination depending on the particle size distribution, i.e., on the nature of the recyclable material, including ink characteristics, and on the extent of contaminant removal required, i.e., on the grade of paper being manufactured.

The separation processes employed also depend on differences in density of the contaminant in relation to that of the fibers and water, and differences in chemical properties *(7)*.

The largest contaminants are removed by screening in the pulper or its associated screen. Hole size is usually 6–20 mm.

In the high-density cleaner, density differences are used to reject the larger heavy material such as stones and staples. The stock is also passed through coarse screens with 1.6 mm holes to remove other large contaminants *(7)*.

In the ink removal stage, which is the heart of the whole process, one or both of two techniques, washing and flotation, may be applied. The usual concentration is about 1%. Washing involves ensuring that the ink is well dispersed in the water and replacing this process water with clean water. In the flotation process, which has been adapted from technology used in the mining industry, the stock is mixed with air and the ink is made to adhere to air bubbles which float to the top of the flotation cell and are removed.

Centricleaners are used after the deinking stage to remove smaller particles of dirt and larger ink particles on the basis of density differences. Fine screens with about 0.25 mm slots are used to remove tacky material, also called "stickies," and other contaminants, and finally a centrifugal cleaner removes contaminants, such as plastic, with a density less than that of the fiber.

The stock, now usually at about 0.6% concentration, is thickened to about 30% with a disc filter and a dewatering press. Residual contaminants are then broken up in the disperser into particles too small to be seen with the naked eye (less than 40 microns). The disperser may also remove ink still attached to the fiber, and may also exert a sort of beating action to improve fiber properties. Further details are given in references *(7, 9, 10)*.

Flotation and washing operations have the greatest effect on pulp brightness and yield *(7)*; however, a prerequisite for successful deinking is that the ink particles are first removed from the fibers. Flotation and washing do not accomplish this; they remove the separated ink particles from the system.

In the flotation process, the ink particles are rendered hydrophobic, air is introduced to the pulp as small bubbles, the ink particles become attached to the bubbles by surface tension and are carried to the top of the cell where the ink-laden froth is removed by overflow or by a mechanical device *(7)*. The process is usually operated at 1.0–1.4% stock concentration. It is effective for particles from 5 microns to 100 microns. Smaller particles are less likely to collide with an air bubble, and larger ones may not be carried to the surface.

Washing is most effective for small ink particles up to about 15 microns. They must be made hydrophilic and dispersed throughout the aqueous phase. This is then removed and replaced by clean water.

Manufacturers of flotation cells and washers have developed equipment with different configurations. Some of the major suppliers and their equipment are noted in **Table II**.

Flotation-deinking and washing-deinking are not interchangeable *(11)*. The main differences are as shown in **Table III**. One of the implications of this comparison is that flotation is preferable for printing papers since fines and fillers are acceptable, but that for products such as tissue washing may offer some advantage *(11)*; however, the processes are often complementary and a deinking plant may include both operations.

A number of other unit operations were discussed in detail at the Jaakko Pöyry Deinking Conference, including both high- and low-consistency cleaning and screening, thickening, dispersion, white water flotation, sludge thickening, and reject handling. Some suppliers of equipment for these operations are noted in **Table IV**.

VI. Economics of deinking *(22)*

Cost of raw materials	*(AUD)*
Cost at source	
Highest (unprinted woodfree waste, Germany)	500/ton
Lowest (household waste, U.S.A., N.E. cities)	*(minus)*40–50/ton
Collection and sorting	
Curbside collection	20–70/ton
Sorting	20–50/ton
Baling	10–30/ton
Transporting to mill	
Baled waste, 200 km	25/ton
Production cost of deinked pulp (DIP)	*(AUD)*
Warehousing cost	
Capital cost of space for 1 ton	1000
Cost for 10 days rotation	5–6/ton DIP
Processing costs	
Plant capital investment for 250-tons/day mill without warehouse and utilities (main process equipment 25% of above)	45–60 M
Doubling of capacity increases investment costs by 40-55%	
Capacity of deinking plants	
Newsprint	320 tons/day
Other	120 tons/day
Yields	
Flotation-deinking (30% magazines)	80–85%
Tissue manufacture (de-ashing required)	70–80%
Variable costs	
Deinking chemicals	50–100/ton DIP
Energy	20–30/ton DIP
Water (3-8 m^3/tons DIP)	1/ton DIP
Fixed costs	3–10/ton DIP
Cost of utilities (water, steam, power, effluent treatment, sludge handling, maintenance)	10–30/ton DIP

Ink setting and release

Various methods of ink-setting are used in printing, including absorption, evaporation, oxidation, heat curing, infrared hardening, precipitation, gelation, and cooling *(4, 14, 15)*. Of these, absorption is the only method which leads, in most cases, to an easily deinkable paper. It is used for newsprint in the letterpress process. The time which has elapsed since printing is important for deinking, and it is often estimated that no printed waste for deinking should be older than six months.

The mechanisms of ink release include wetting, fiber swelling, emulsification, solvation, saponification, dispersion, mechanical treatment, and processes to prevent redeposition. The occurrence of specks which are difficult to remove increases from Groups 1 to 4 in **Table V**, and depends on whether the paper is coated or not and on the method of ink setting *(4, 9)*.

Among the chemicals used in various stages of the deinking system are sodium hydroxide, sodium carbonate, sodium silicate, hydrogen peroxide, sequestrants, collectors, calcium ions, polyphosphates, dispersing agents, displectors, acids, talc, aids for white water flotation, e.g., bentonite, and aids for dewatering ink sludge *(4)*. Some attention was given at the conference to the chemical reactions and mechanisms involved in deinking *(4)*.

Pulp quality

The changes which take place in fiber quality with each cycle, and their underlying mechanisms, constitute a large subject which is beyond the scope of this article. With each cycle, there is a loss of intrinsic fiber properties which is due, in considerable part at least, to the effects of drying *(16)*. There now appears to be general agreement *(7, 17)* that recycling causes a major reduction in breaking length, burst, and fold with a lesser reduction in density and stretch, and with increases in tear, stiffness, scattering coefficient, opacity, and air permeability. However, a decrease in tearing strength with successive cycles was found in laboratory studies on air-dried eucalypt chemical pulps *(16)*.

Control of the brightness of deinked pulps by selection of feedstock, optimizing the deinking process, particularly the flotation stage, and the use of bleaching chemicals such as peroxide is an important aspect of pulp quality *(7)*. The removal of stickies is also of major importance.

Some papermakers have observed no adverse effects of incorporating substantial amounts of deinked pulp in the furnish, in respect to runnability *(7)*, but one report mentions efficiency losses of 1–2.5% at several mills *(18)*.

Environmental considerations

Contrary to some popular opinion, paper recycling is not without environmental cost. Even a relatively simple deinking plant may require 2% sodium hydroxide, on a fiber basis, to aid in fiber dispersal *(19)*, and yields of 80–85%, or lower, are common *(13)*. Deinking effluent is often high in BOD from dissolved starch. The presence of starch and other polymers may make it difficult to remove suspended solids by conventional sedimentation techniques, even when deinking is not involved. Dissolved salts and heavy metals (which may be present if certain types of ink have been used) may be thought to contribute to an environmental problem in disposing of deinking plant effluent, but it has been pointed out that the heavy metal levels are lower than most animal manures and certainly lower than the levels found in sewerage sludge *(13)*.

Other aspects of the environmental side of deinking include the beneficial effect of relieving pressure on landfill sites, which has been a major incentive for recycling in the United States, resource conservation, and energy conservation. In Australia, about half of the wood for pulping is plantation-grown pine, mainly radiata, and hardwood sawmill residues are also used extensively *(2, 13)*. Hence recycling does not have as significant an influence on the conservation of native eucalypt forests as is often thought. As regards energy, pulp made from recycled fiber may require only 450 kWh/metric ton, as against about 2800 kWh/metric ton for radiata pine TMP, for example *(13)*. Any reduction in electricity requirements is very beneficial economically, and also environmentally, particularly where the power is derived from coal burning. The difference in energy requirements between recycling and mechanical pulping is reduced by the fact that collection and transport of wastepaper requires more energy than the transport of pulpwood *(13)*.

Sludge disposal is commonly effected through landfill, composting with other wastes such as bark, or burning, but deinking sludge may have a high ash content and consequently a poor fuel value *(13)*. The landfill option is becoming increasingly unpopular because of rising costs.

Liquid effluents from wastepaper pulping are similar to those from mechanical pulping, the following loads being typical *(13)*: biochemical oxygen demand: 20–30 kg/metric ton; chemical oxygen demand: 50–60 kg/metric ton; nonfiltrable residue: 10–50 kg/metric ton.

Representative samples of Australian wastepaper were deinked in a laboratory unit *(13)*. Small quantities of 2,3,7,8-tetrachlorodibenzofuran and of 2,3,7,8-tetrachlorodibenzodioxin were found in the feedstock, which were attributed to kraft pulp, bleached by the older technology, in the magazine component of the wastepaper. No 2,3,7,8-TCDD was detected in the liquid waste at the 1pg/L (ppq) level.

The deinking process uses sodium hydroxide and produces salts, the disposal of which could be a major environmental issue at an inland location *(20)*.

Future directions

"The market opportunities for recycled fiber will be strong in the '90s. While packaging grades have used a high proportion of recycled fiber in the past, particularly in Australia, the main growth area will be with deinking in newsprint, tissue, and printing and writing grades *(1)*".

Impediments to further recycling in Australia are sometimes seen in terms of economic realities which favor the manufacture of virgin pulp, e.g., waste management charges, pulpwood prices, energy and water costs, and transport and handling charges *(21)*. With the necessity for Australia not only to reach self-sufficiency in pulp and paper products but to develop export markets for value-added products such as bleached chemical pulp, it would seem, however, that all sectors of the industry should be given as much encouragement as is compatible with a balanced environmental policy. It is best that the economics of recycling should continue to be made more attractive by technological improvements, such as fiber fractionation and deinking technology. The high cost of domestic collection and segregation appears to have been overcome by community cooperation *(1)*. Segregation of household recyclable materials at the source, and the willingness of local councils to integrate recycling collections with household rubbish (garbage) collection will make wastepaper costs more competitive *(1)*.

The most immediate item on the agenda in Australia in this field is the use of deinked waste in newsprint production. This is likely to be followed by the incorporation of a much higher level of deinked fiber in tissues and fine papers produced in Australia. Some constraints may be imposed by the geographical location of some mills, far from concentrated sources of wastepaper, with consequent high transport costs. This is perhaps an area where government intervention could assist by the implementation of policies favoring lower interstate shipping costs.

In the United States, the paper industry has set the goal of collecting and recycling 40% of total paper production by 1995. The present collection rate is 30% and the utilization rate 24%. In Australia, although the utilization rate has increased to 46.6% *(1)*, it is possible that some state governments may follow the example of many U.S. states and legislate for increased wastepaper use. For example, Victoria is considering the enactment of legislation requiring a fixed percentage of recycled fiber in all newsprint used in that state *(13)*.

It is surprising that very little collaboration appears to exist between ink manufacturers and paper manufacturers using deinking technologies. While research is directed on the one hand towards making ink stick to the fiber, the other group is concerned with making it come off more easily. Some progress may be expected in the future in cooperative efforts. A start has been made: in Germany, the authorities producing directories have been prevailed upon to change the inks, so that the directories can be mixed with household papers *(12)*. Australia should do the same.

Economics of deinking

A comprehensive account of the economics of deinking was presented to the Deinking Conference *(22)*, from which the data in **Table VI** have been extracted. The cost figures refer to the recent Western European situation, unless otherwise specified, but are expressed in Australian dollars (AUD). (One AUD is US$ 0.78, Nov. 2, 1991.)

The cost of waste materials depends on the source, e.g., converting waste, printing waste, unsold newspapers and magazines, office waste, and household collection.

In Australia, the average price received by wastepaper collectors in 1989 was AUD 47.6/ton. The lowest prices, AUD 30, were received in areas of Western Australia and Tasmania outside the capital cities, and the highest, AUD 65.7, in outer New South Wales *(23)*. □

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The author is indebted to A.W. McKenzie for helpful discussions. The subject matter of this article was gleaned largely from a recent deinking conference in Australia cosponsored by Appita and Jaakko Pöyry Pty. Ltd.

Keywords: Australia, costs, deinking, economics, forecasts, ink, New Zealand, pollution control, pulp, reclaimed fibers, recycling, wastepapers.