A waste management program for paper mill sludge high in ash

Ken Diehn and Barry Zuercher

A comprehensive waste management program reduced Pope & Talbot's dependency on landfilling by 78%.

The Federal Water Pollution Control Act Amendments in 1972 directly affected mills with point source discharges to surface waters. To meet the effluent guidelines, most pulp and paper mills use primary sedimentation clarifiers and some form of secondary biological treatment system. These systems generate solids that are dewatered into sludge, which requires disposal.

The pulp and paper industry generates approxmiately 2.3 million tons of sludge annually in North America (*1*). Aggressive regulatory programs of waste reduction and recycling are being instituted in the United States because a crisis in solid waste is perceived. In Wisconsin, the Dept. of Natural Resources (WDNR) has set a waste reduction goal of 75-90% for pulp and paper mill sludge. This percentage range represents 1.1-1.4 million tons of sludge per year for Wisconsin mills (*2*).

The concept of integrated waste management

Pope and Talbot operates a tissue mill in Eau Claire that deinks high-grade wastepaper. The sludge generated from the deinking and papermaking operation is high in ash and low in fiber. The primary means of disposal for this type of sludge has been landfilling.

Initially, the Eau Claire operation utilized two vacuum filters with 500 ft^2 of filtering area each to achieve 22% sludge solids. Approximately 66 tons/day were transported to the municipal and county landfills for disposal.

In 1977, the company decided to operate its own landfill for disposing of paper mill sludge. The 19-acre landfill has a design capacity of 1.2 million cubic yards. The landfill was designed as three trenches that would be filled in distinct modules. The projected life expectancy of the landfill was 11 years, based on 1977 sludge generation rates.

Several operational difficulties were encountered at the outset as a result of the high ash content of the sludge. Precipitation caused saturation levels to be reached in the landfilled sludge, and ponds formed on the sludge surface. Low permeabilities of 3.6×10^{-7} cm/s were not uncommon. The surface contact water was then treated the same as pore water, which meant collecting and treating it at the wastewater treatment plant.

In any effort to keep the water off, the sludge cannot be sloped greater than about 3%. Attempts to achieve slopes greater than 3% caused it to slide or shift. This movement has been called a "sludge wave." These waves are strong enough to cause the berms to slough, so slopes greater than 3% had to be avoided. Another difficulty was that odors were released when sludge was placed and compacted. These odors were caused by the microbial activity in the upper layers of the fill.

The operational difficulties were attacked through revised plans of operation. These plans were reviewed by various regulators, including the town board, the county zoning committee, and the WDNR. In 1987, Pope & Talbot designed an integrated waste management program that was presented to the regulatory community. The program was designed to achieve three goals:

1. The emphasis would be on resource recovery and recycling.
2. The total waste volume would be dramatically reduced.
3. The dependency on landfilling would be minimized.

Under the waste management program, the waste reduction goal proposed by the WDNR is achievable. The largest contribution of the program is the change in the company's focus from disposing of generated wastes to finding beneficial uses for it.

The development of the integrated waste management program

The waste management program encompasses four disposal options:

1. Landspreading sludge
2. Reduction of sludge to ash by combustion
3. Landfilling ash
4. Landfilling sludge.

The selection of these disposal options was based on the nature of the sludge, the surrounding ecological environment, the mill's projected disposal costs, and disposal efficiencies.

Diehn is solid waste supervisor and Zuercher is division technical director, Pope & Talbot, Consumer Products Division, Eau Claire, Wis. 54703.

I. Comparison of heavy metal concentrations of the mill's ash and sludge with other agricultural by-products (*13*)

	Cadmium	*Copper*	*Lead*	*Nickel*	*Zinc*
In ash,[a] mg/L	0.5	60.2	18.6	13.2	114.0
In sludge,[b] mg/L					
Average quarterly	n.d.	78	4	0.6	424
Maximum quarterly	n.d.	113	17	5.0	600
Maximum number of applications[c]	no limit	23.0	608.0	209.0	8.7
Range for soils,[d] mg/L	0.01-7	2-100	2-200	10-1000	10-300
In top soil, mg/L	1.30	47	23	170	42
In manure,[e] mg/L					
Cow	1.0	42	14	200	48
Poultry	1.9	485	26	20	425

[a]Rotary-kiln-fired ash, April 1989 sample.
[b]Quarterly samples for 1989.
[c]Max. number of 22.5-tons/acre applications (5).
[d]From Ref. 14.
[e]From Ref. 15.

Landspreading

In 1987, field studies and laboratory germination tests were conducted to determine the impact on soils and plant uptake from sludge and sludge-amended soils.

Three benefits were observed in the laboratory tests. First, the germination rate in the sludge-amended soil was equal to or greater than the control. Second, the root development was greater in the sludge-amended soil than in the control. Third, the capacity to hold moisture was greater in the sludge-amended soil than in the control (*3*).

To determine the proper rate of sludge application, or the optimum distribution of sludge over an acre, studies were conducted on test plots to analyze soil, plant tissue, and sludge. At application rates of 22.5 tons/acre, no problems with phytotoxicity, soil buildup, plant uptake, or crop rotation were encountered (*4*). At a one-time application rate of 22.5 tons/acre, the cumulative total metal loading is 89% below the guidelines outlined in WDNR's Technical Bulletin No. 88 (*5*).

One concern for landspreading paper mill sludge is the potential for nitrogen immobilization. When the sludge is plowed under, the available ammonia or nitrate is temporarily immobilized by the bacteria that decompose the residues. After plowing, the sludge begins to decompose, and the nitrogen that was immobilized is released in a form available to the active organic life. Under ideal weather conditions, the release of immobilized nitrogen begins about one month after plowing or disking of the organic matter (*5*).

There are three approaches that reduce or eliminate the immobilization problem:

1. Limit the sludge application rate.
2. Prescribe a waiting period between sludge application and planting.

II. Physical analyses comparing the mill's sludge and ash

	Sludge	*Ash*
Average weight, tons/day	109	50
Bulk density, lb/ft³	40.2	28.7
Permeability, cm/s	1×10^{-7}	4×10^{-5}
Moisture, %	55	22
Ash, %	22.0	77.0
Volatiles, %	18.4	1.0
Fixed carbon, %	0.81	1.96
Sulfur, %	0.03	0.08
Heat value, BTU/lb	1599	...

III. Heating value of sludge, illustrating the possible net loss in BTUs during sludge combustion

	Loading rate to kiln, lb/h	*Heat value*		*Heat needed to raise to 2000°F, BTU*	*Net loss, BTU*
		BTU/lb	*BTU/h*		
Fiber	3486	3882	13.5×10^6		
Clay	4264	0	0	$3.6 = 10^6$	
Water	9473	0	0	22.7×10^6	
Total	17222		13.5×10^6	26.3×10^6	12.8×10^6

3. Add supplemental nitrogen fertilizer to meet the requirements of soil microorganisms (*6*).

To solve the problem of nitrogen immobilization, Pope & Talbot selected the first approach, which provides beneficial use of its sludge at the application rate of 22.5 tons/acre. This approach reduces the need for additional supplemental nitrogen fertilizer to meet the requirements of soil microorganisms.

Neither the chemical nor physical characteristics hinder the use of sludge as a soil amendment on agricultural land. **Table I** compares heavy metal concentrations of the mill's wastes with other types of by-products used for amending soil (*13*). **Table II** shows the physical characteristics of the sludge used in landspreading.

The soils of two surrounding counties, Eau Claire and Dunn, are similar, and they provide thousands of acres suitable for landspreading of paper mill sludge. Two soil types in these counties are Menahga and Plainfield. They are described as "excessively drained sands and loamy sands that are underlain by loamy sand and sand and are nearly level to sloping" (*7*). In Eau Claire County alone, these two types make up over 31% of all soils.

Since the regional soils have rapid permeability and low fertility, the sludge, with its high clay content, can appreciably increase germination, root development, soil tilth, and water-holding capacity. Landspreading the paper mill sludge in this region has proven beneficial.

The WDNR approved landspreading of Pope & Talbot sludge in October 1987. The landspreading program has stringent setbacks, or buffers. Sludge can be placed no closer than 300 ft from "navigable" streams or lakes, 250 ft from a private well, 1000 ft from a public water system (including churches, stores, town halls, etc.), 25 ft from a property line or public road, 500 ft from a residence (can be reduced to 250 ft with owner's permission), and 75 ft from a wetland, or drainways at the base of a field.

Additionally, there must be at least a 3-ft separation from the soil surface to either bedrock or the groundwater table at its seasonally high level. These depths are derived from soil maps and sometimes from soil borings.

Sludge combustion

The rising costs of siting, designing, and operating a landfill have now made the economies of sludge combustion attractive. However, the sludge solids content had to be raised to 45% to reach a reasonable combustion efficiency. This required the replacement of the two vacuum filters with two twin-wire belt presses.

Feasibility studies were conducted that focused on projecting the volume reduction and the ash characteristics. Because of the capital investment required, the company chose to contract with an energy resources company to design, own, and operate a steam-generating facility. This facility was capable of burning 130 tons/day of paper mill sludge and of providing a stable source of 100,000 lb/h process steam at 240 psi at 430°F (220°C).

The bottom ash would fall from the discharge end of the kilns and would enter a quench tank. Fly ash from the boiler and baghouse would be collected in hoppers and combined with the bottom ash by means of a conveyor. The anticipated composition of the combined ash was 70–80% bottom ash and 20–30% fly ash. Rotary air locks were designed to control air leakage.

Because of WDNR concerns over metal leaching from acidic leachate washing through the deposited ash, no paper mill sludge could be placed over the ash.

Landfill operation

The waste management program demanded that operational changes be made at the landfill. The landfill would be used for sludge on an emergency basis, when no other disposal options were available. After the combustion unit was started up, all ash would be deposited at the company landfill until alternative uses could be found.

Because of the reduced landfill activity, open areas could remain idle for years at a time. It was necessary to construct a final cover on areas that had reached the design grade. Areas that would be inactive for an extended period but were not at final grade would receive an interim cover.

It was necessary to keep active working areas small. Odors that might develop in the sludge working area would be controlled with a surface application of potassium permanganate. The working area for ash disposal would receive a daily cover of sand or other suitable material to control wind-blown dust.

Because a large portion of the landfill would be receiving an impermeable cover, surface water from precipitation would have to be drained. The interim cover would be sloped towards a surface drainage system that would remove the water to an unlined detention pond, where it would be allowed to filter into the soil.

Implementing the waste management program

To implement the program, sludge solids needed to be increased. Because sludge cake with a higher solids content reduces the volume, transportation costs for landspreading and landfilling would be reduced. Higher solids content would increase the heat energy value and improve combustion efficiency.

By replacing the two vacuum filters with two twin-wire belt presses, sludge cake solids were raised to 42–45%. This action reduced the sludge volume by 13%.

Landspreading

The landowners in the area readily accepted the use of sludge as a soil amendment. Because of the demand, a backlog of 500-1000 available acres can be maintained without advertising. The most difficult period is during summer, when the fields are planted, but enough fallow land was available in 1988 and 1989. County agricultural agents have endorsed the program, on the condition that care is taken to avoid soil compaction (*8*).

In Eau Claire and Dunn Counties, approximately 160,000 acres of crop land and pasture are potentially suitable for landspreading. Allowing 22.5 tons/acre at 31,000 tons/year, there is a potential for 100 years of landspreading. However, the availability of suitable land is limited by crop rotation and planting seasons.

Pope & Talbot maintains full responsibility for the loading, hauling, spreading, and incorporation of the sludge. The loading rate is 22.5 tons/acre, which results in a blanket about 1.2 in. thick. The plan of operation stipulates that the sludge must be spread within 24 h of

IV. Comparisons of sludge and ash toxicity with WDNR groundwater standards

	EP[a] toxicity		*ASTM*	*Groundwater standards*	
Element	*Sludge, mg/L*	*Ash, mg/L*	*Ash, mg/L*	*PAL,[b] mg/L*	*ES,[c] mg/L*
Arsenic	...	...	0.021	0.005	0.050
Barium	0.521	0.003	<0.002	0.2	1.0
Boron	...	...	<0016	...	...
Cadmium	0.006	0.032	<0.004	0.001	0.010
Chloride	...	...	<1.0	...	...
Chromium	0.019	...	0.009	125	250
Copper	...	...	0.023	0.5	1.0
Iron	...	...	<0.004	0.15	0.3
Lead	<0.046	<0.046	<0.002	0.005	0.050
Magnesium	...	...	0.884	...	...
Manganese	...	...	<0.005	0.025	0.05
Mercury	<0.077	<0.077	<0.0002	0.0002	0.002
Molybdenum	...	...	0.056	...	...
Nickel	...	...	0.451	...	...
Potassium	...	...	<1.5	...	...
Selenium	<20	<20	<0.005	0.001	0.010
Silver	<0.005	<0.005	<0.005	0.010	0.050
Sodium	...	...	1.6	...	...
Zinc	...	...	0.072	2.5	5

[a]EP stands for "extract procedure." This is an ASTM test method for leachability. [b]Preventative action limit. [c]Enforcement standard.

unloading. The sludge must then be incorporated within 72 h of spreading.

Since 1986, 88,000 tons of sludge have been landspread on 1800 acres, on 44 different farms. About 800 acres/year are needed at the current loading requirements.

Sludge combustion

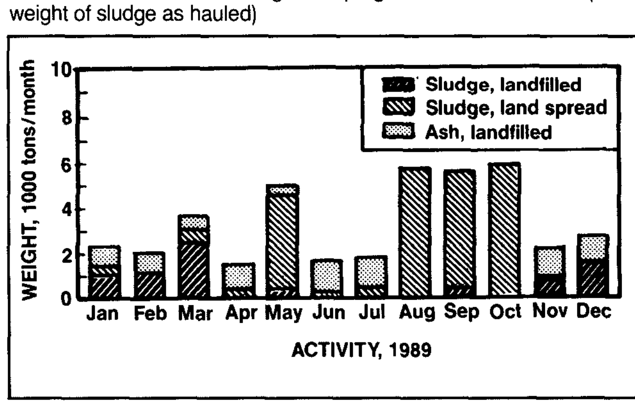
Even at 45% solids contents, the sludge still does not meet the requirements for self-sustaining combustion, because the sludge is below the 6000 Btu/lb threshold and the 66.5% organic content requirement (*9*). In fact, **Table III** shows there is a net loss in heat when this sludge undergoes combustion.

The steam-generating facility reduces waste volume by 3:1 and residue weight by 4:1. Table II summarizes the physical characteristics of the ash. As shown in **Table IV**, the potential toxicity of the ash is considerably less than the sludge. The plan of operation for the steam-generating plant is to fire sludge during the five winter months. The reason for this is to make full use of the 65,000-lb/h base loading of the plant.

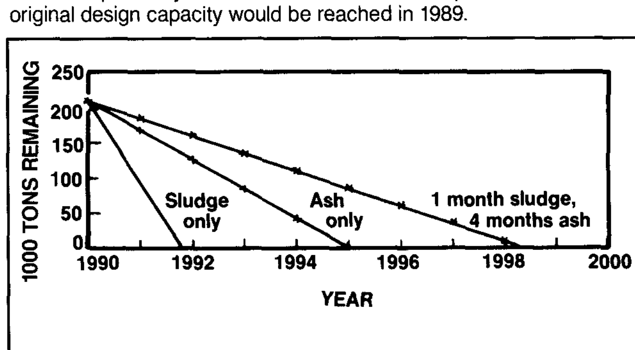
Although a wet ash system was originally proposed, the ash-handling system had to be retrofitted to a dry system to accommodate the high kiln exit temperature of the ash and the abrasive nature of the ash (*10*). The ash is comparable to a fine or medium sandy silt with 52% passing through a No. 200 sieve.

The ash has been hauled to the company landfill for disposal. To prevent the ash from blowing in transit, tarps were added to the same trucks used to haul sludge, and water is added to the ash to reduce dusting during unloading.

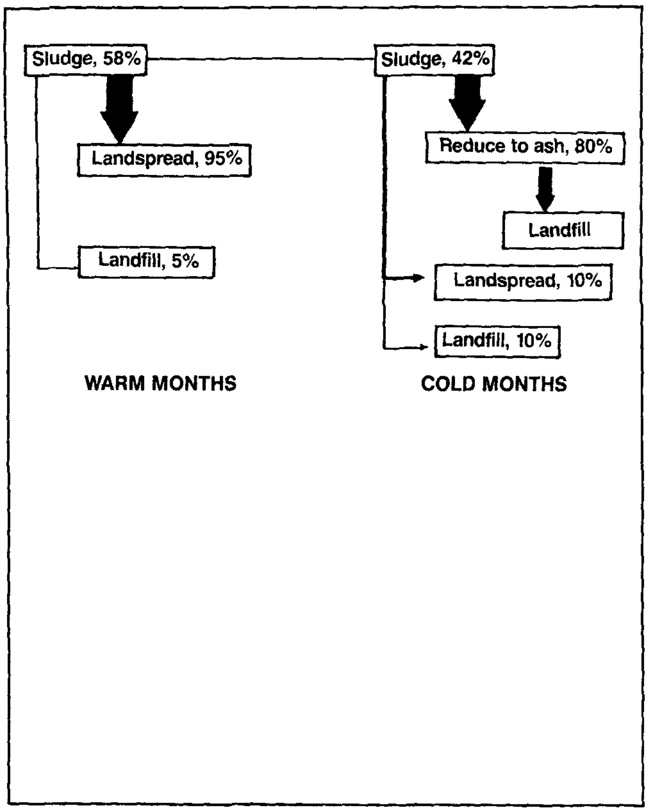
1. Results of the waste management program for 1988 and 1989 (actual weight of sludge as hauled)



2. Life expectancy of the landfill for various disposal scenarios. The original design capacity would be reached in 1989.



3. Solid waste disposal options illustrating changes in the disposal emphasis during different seasons



Landfill operation

The program still demands the ability to landfill. However, this dependency on landfilling is diminished by the other disposal options, so landfilling is utilized only when the other options are unavailable.

In 1987, Trench 1 and part of Trench 2 were permanently capped. The remainder of Trench 2 received an interim cover, and a drainage system was installed in 1988. A detention pond for a "10-year precipitation event" was constructed and put into operation. (A "10-year precipitation event" is the WDNR term for the maximum rainfall event that is statistically probable once every ten years.) Utilizing smaller working areas and implementing odor control techniques dropped the number of complaints. The impermeable cover has reduced percolation, and the amount of leachate generated has declined from 5.8 million gallons per year in 1986 to 2.3 million gallons in 1989.

About 1.5 acres are used for sludge disposal. This area is treated with lime occasionally to control odor, and any contact water is removed for treatment as soon as practicable.

The landfill has approximately 210,000 cubic yards of capacity remaining. The plan is to burn sludge for five months and landspread sludge for seven months. **Figure 1** illustrates that one and all options may be used in any one month. At this rate, the life of the landfill is extended to 8-10 years, as shown in **Fig. 2.** If other alternatives can be found for the beneficial reuse of ash, the life expectancy of the landfill could conceivably reach 20-30 years.

The 1.5-acre area used for ash disposal receives a daily cover to prevent the blowing of ash at the landfill. During the summer, a minimal cover of sand is used. In winter, wood chips, derived from the landscaping industry, have proven successful. **Figure 3** shows that the primary mode of operation will be landspreading during the warm months, from mid-April to mid-November, whenever land is available. Any short-term interruptions in landspreading due to inclement weather would result in the use of the landfill. Avoidance of landfilling allows the landfill to stabilize. Conditions apparently become more static and less troublesome when landfill activity is kept at a minimum.

Figure 3 further illustrates that during the cold months, from mid-November to mid-April, the emphasis will be put on sludge burning. The ash will be placed at the landfill. During gas shortages or mechanical breakdowns, sludge will be landspread if weather permits. Otherwise, sludge will be placed at the landfill as a last resort.

Before this program began, 100% of the sludge was landfilled. In 1985, 86,526 wet tons of sludge were produced. As illustrated in **Fig. 4**, 1988 was the first year that the new program was fully operational. In that year, 38% of the sludge was landfilled, 36% was landspread, and 6% of all sludge was burned. In 1989, 10% of the sludge was landfilled, 36% was landspread, and 54% was burned. In 1990, the company anticipates landfilling 8% or less sludge, landspreading 58%, and burning 33% of the sludge. This strategy results in a reduction of 85% in landfill use from 1985 through 1990, as shown in **Fig. 5**.

The landfill was originally estimated to reach design capacity in 1989. With the implementation of this program, final closure will be delayed for at least 10 more years.

The future of the waste management program

Our company is exploring the beneficial use of the ash. The ash may be suitable as a liming agent. While aglime is essentially calcium carbonate, the ash is a highly complex mixture of metal oxides. To estimate the ash's neutralizing index, an analytical procedure has been developed to simulate the multi-year process by which lime reacts with the soil *(11)*. Other possible uses would be as a porous filler in concrete or as a gravel substitute for road base *(12)*. The market for such beneficial applications has only opened up in the past five years, so market strategies are still under development.

Using the extract procedure of the American Society for Testing and Materials (ASTM), one ash analysis showed that arsenic exceeded the preventative action limit (PAL). However, the amount did not exceed the enforcement standard (ES) of the State of Wisconsin's Public Health-related groundwater standards, as shown in Table IV.

Table IV also charts an EP toxicity analysis that was conducted on the same sample. Results showed no detection of arsenic but an exceedance for cadmium. All other parameters were below established limits *(16)*. These results indicate that the beneficial use of ash is possible.

The current landspreading permit expires in June 1991. In reapplying for the permit, the company plans to negotiate with the WDNR the setback requirements imposed on landspreading by the WDNR. It is felt that some of the setbacks are excessive, preventing landspreading on land that otherwise is acceptable.

Conclusions drawn from a winter landspreading study conducted by Pope & Talbot during the winter of 1988-

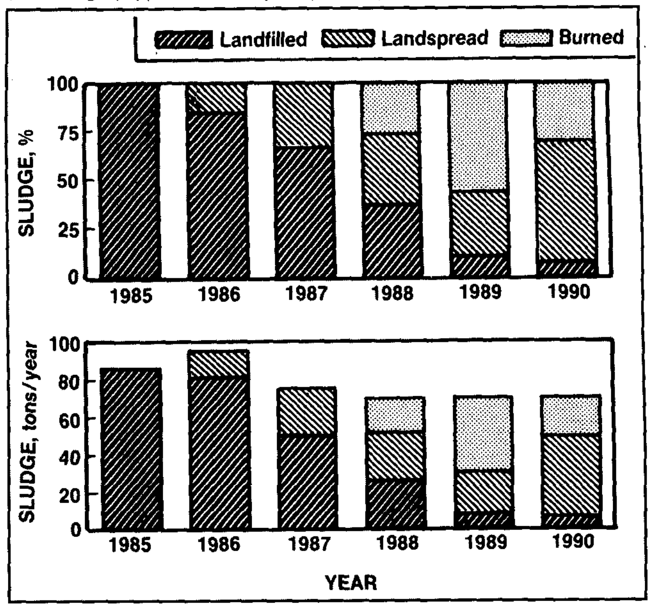
89 support the opinion that several of the setback restrictions could be relaxed. Sludge spread on slopes of 2-4% and 4-6% over both bare frozen ground and snow-covered ground demonstrated that sludge does not physically migrate when spread on slopes of 6% or less, regardless of the date of application. The sludge blanket maintains a higher soil moisture than does bare ground and provides more moisture during spring planting (*17*).

Conclusions

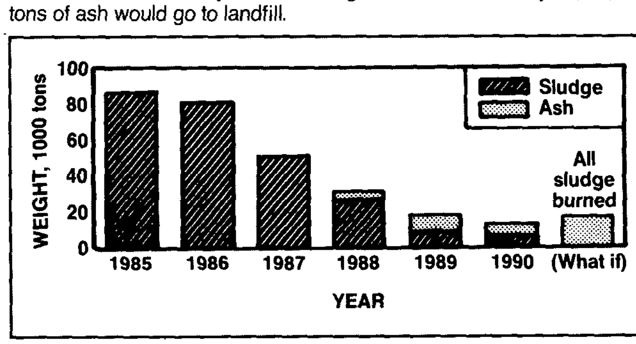
The operation of this program reduces the amount of solid waste generated, emphasizes recycling and beneficial use, recovers energy by incineration, and continues environmentally sound landfill practices. With the implementation of this program, the disposal demands for sludge have been stabilized economically for the mill. Landspreading has proven less costly than landfilling. Burning sludge is cost effective when it avoids the capital costs of landfill siting and construction and provides a reliable source of the mill's process steam demands.

This plan for the Eau Claire operation is an example of a comprehensive waste management plan. Each waste management plan must be tailored to meet the nature of the sludge, the surrounding ecological environment, and the mill's economical disposal efficiencies for each disposal option. A proactive strategy needs to be developed and implemented by the pulp and paper industry, or the regulatory community will dictate its own strategy for meeting the nation's solid waste crisis. A sound waste management program should be cost effective and flexible enough to change with the evolving methods of waste recovery and waste minimization.□

4. The total amount of sludge landfilled, landspread, and burned in percentage (top) and in tons/year (bottom)



5. Sludge and ash placed at the landfill projected to 1990, showing 85% reduction in tons/year. If all sludge were burned one year, 16,425 tons of ash would go to landfill.



Literature cited

1. Amberg, H., Sludge dewatering and disposal in the United States pulp and paper industry, NCASI Technical Bulletin, No. 552, 1988.
2. Reindl, J., Waste reduction and recovery, recommended goals and implementation programs, WDNR Bureau of Solid Waste Management, Madison, Wis., June 1985.
3. Supplement to the application for approval of land application of paper mill sludge for Pope & Talbot, Ayres Associates, Eau Claire, Wis., March, 1987.
4. Phytotoxicity documentation report, Ayres Associates, Eau Claire, Wis., January 1988.
5. Keeney, D. R., Lee, K. W., and Walsh, L. M., Guidelines for the application of wastewater sludge to agricultural land in Wisconsin, WDNR Technical Bulletin No. 88, 1975.
6. Simpson, G. G., King, L. D., and Carlile, B. L., Land application of kraft paper mill sludge, Proceedings of the Fifth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste, Univ. of Wisconsin-Extension, Madison, Wis., Sept. 1982.
7. Soil survey of Eau Claire County, Wis., a publication of the U.S. Dept. of Agriculture, Soil Conservation Service, in cooperation with the Research Division of the College of Agriculture and Life Sciences, University of Wis., 1977.
8. Kraemer, C. E., Special news release, Chippewa County Agricultural/Resource Agent, Dec. 23, 1986.
9. McGovern, J. N., Berber, J. G., and Bockheim, J. G., Tappi J. 66(3): 115(1983).
10. Aspetarte, T. R., Rosenfield, A. S., Smale, B. C., and Amberg, H. R., Methods for pulp and paper mill sludge utilization and disposal, EPA Report No. RZ-73-232, 1973.
11. Ochrymowycz, L., Estimation of the neutralizing index (NI) equivalent of Ladysmith incinerator ash, University of Wis., Eau Claire, Wis., 1988.
12. Fraser, J. L. and Lum, K. R., Environmental Scientific Technical (17): 52(1983).
13. Hatch, C. J., Pepin, R. G., Tappi J. 68(10): 71, 1985.
14. Fate and effects of trace metals in sewage sludge when applied to agricultural land, EPA Report No. RZ-73-232, 1973.
15. Perkins, D., Analyses of purchased agrigultural by-products (dry weight basis), Portland Water District, Portland, Me.
16. Public health related groundwater standards, Wis. Dept. of Natural Resources, Administrative Code Chapter NR 140.10, Madison, Wis., October 1988.
17. Winter sludge spreading study, Ayres Associates, Eau Claire, Wis., June 1989.

Received for review Jan. 16, 1990.

Accepted Jan. 18, 1990.

Presented at the 1990 Environmental Conference.