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IRRIGATION OF SLASH PINE WITH PAPER MILL EFFLUENTS

Jacques R. Jorgensen, Soil Scientist
Southern Forest Experiment Station
Forest Service, U. S. Department of Agriculture
Alexandria, Louisiana

Near Alexandria, Louisiana, the U. S. Forest Service has studies under way to determine whether or not pine trees can be irrigated with waste waters from paper mills. Promising leads have been uncovered that will guide research and industry in perfecting irrigation as a system of disposal.

The pulp and paper industry of the South must dispose of more than a billion gallons of effluents each day. This spent water contains salts and organic residues that cannot be recovered economically. It must be filtered or diluted before it can be reused. Principal irorganic constituents are sulfates and chlorides of sodium. Organic residues include cellulose, hemicellulose, lignin, and their derivatives. The dissolved and suspended materials, which add a dark color and strong odor to the water, will kill fish and other aquatic life if present in sufficient concentrations.

In the past, the paper industry depended largely on natural stream flow to dilute the effluents and reduce their toxicity. This procedure is rapidly becoming obsolete because of increasing demands for fresh, clean water for domestic, industrial, and recreational use. Thus, other ways to dispose of the waste are being sought. Several alternatives are available; filtration, impoundment, application to land, and irrigation are the most prominent.

Disposal through irrigation has several advantages. It requires no expensive plant or impoundment and is superior to land application because growing vegetation transpires large amounts of moisture. During the summer months of June, July, and August, for example, an acre stocked with trees transforms about 8 acre inches, or 216 thousand gallons, of water into vapor per month. This is in addition to any water that percolates into the soil. Irrigation with effluents can also increase crop yield, especially on porous soils that develop serious water deficiencies during periods of low rainfall (3).

Irrigating pines with paper mill waste water sounds like an ideal solution to the problem. But the residues in the water may be harmful to plants, just as they are to aquatic life. Thus the suitability of effluents for irrigation depends on the concentration of impurities.

This paper will review the principal properties of kraft paper mill effluents that limit their use for irrigation. The second portion of this paper reports results of two studies in which slash pine seedlings were irrigated with different kinds and concentrations of waste waters.

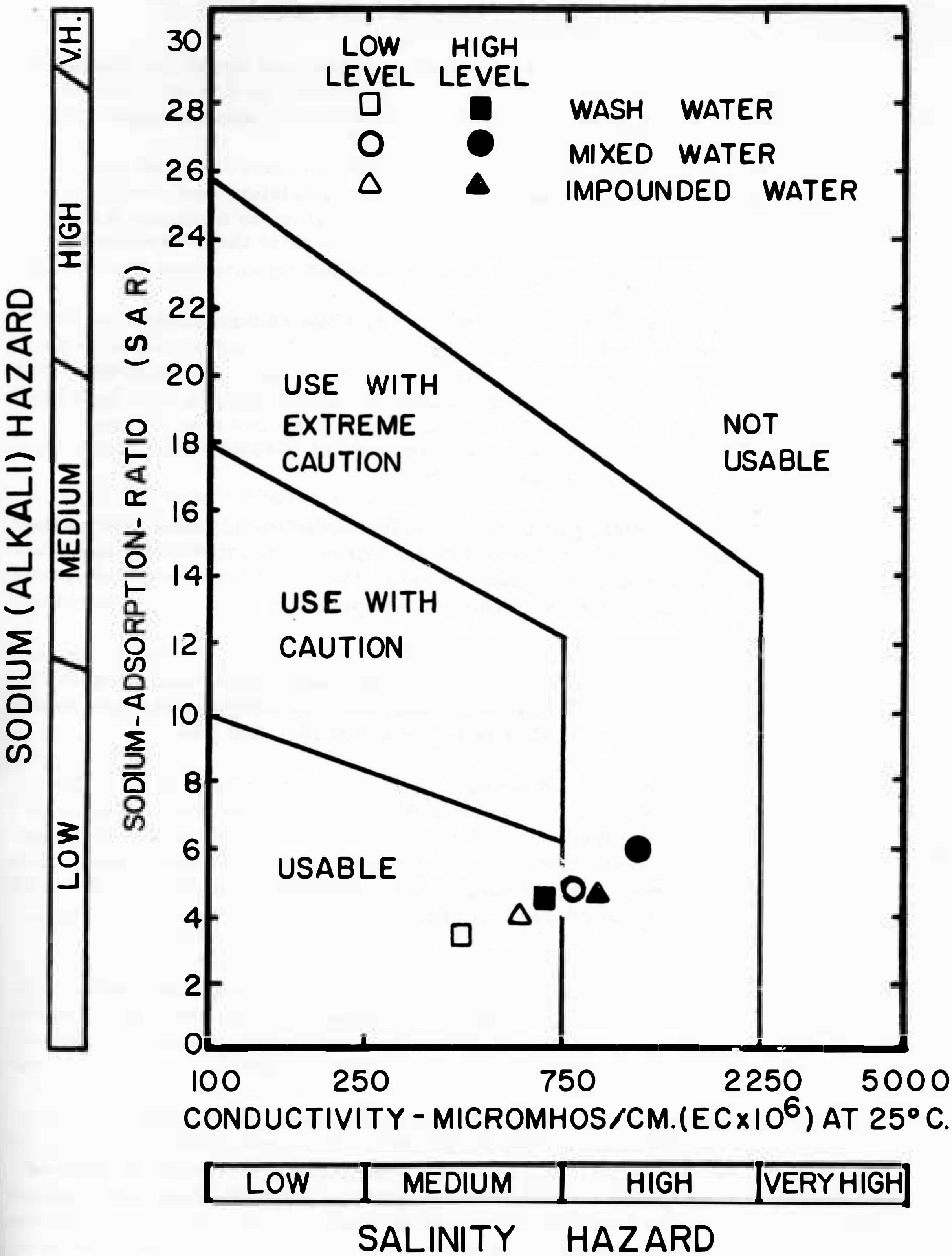

Figure 1 - How the Various Diluted Effluents Used in Studies Rate as Irrigation Waters.

Water Quality

The four properties that usually affect the suitability of water for irrigation are amount of soluble salts, proportion of sodium in relation to divalent cations, concentration of bicarbonates, and pH, which is related to the salts present.

Conductivity, an expression of the soluble salt concentration, and sodium-adsorption-ratio (SAR), the relative portion of sodium to calcium and magnesium, are two criteria used by the United States Salinity Laboratory to measure the suitability of a water for irrigation (4). The Laboratory refers to them as salinity and sodium hazard. Figure 1 shows their combined effect on water quality.

Waters with low or medium salinity hazard and low sodium hazard may be used almost indiscriminately for irrigation. Those of low or medium salinity but with medium sodium hazard are intermediate. Soils receiving them must be flushed periodically to remove toxic accumulations of salts. Waters with high salinity or sodium hazard require extreme caution in their use and may be applied only to well-drained soils, even with special management. Waters with higher values of either are unsuitable for irrigation.

Concentration of the bicarbonate ion in irrigation water is measured by the residual-sodium-carbonate value. This is the amount by which carbonate and bicarbonate ions exceed calcium and magnesium ions. Waters with less than 1.25 milliequivalents/l of residual sodium carbonate are probably safe for irrigation.

A fifth factor, organic residue, is usually not considered in normal irrigation waters, but it may be important in paper mill effluents. Some authorities (1, 2) believe the organic content is of minor importance in irrigation as long as the biochemical oxygen demand (B. O. D.) is below 2,000 to 5,000 ppm.

Three effluents collected weekly from kraft paper mills have been included in our studies. One is from a north Louisiana mill's impounding basin, where all liquid wastes are accumulated from March through October. The second is wash water collected directly from the discharge flume of a central Louisiana mill. The third, called black water, is the strong waste from an impoundment at the latter mill. It constitutes about 20 percent of the mill's total effluent; the remainder is wash water.

The salinity hazard, sodium hazard, residual sodium carbonate, and B. O. D. of these effluents indicate their potential for irrigation. They are shown in Table 1 for the basic waters and for a mixture containing 80 percent wash water and 20 percent black water.

Residual sodium carbonate and B. O. D. of all the effluents are well within allowable limits for irrigation water (Table 1). Both salinity (conductivity) and sodium hazards are high enough to suggest that considerable dilution is needed before any of the effluents can be used indiscriminately. In central Louisiana, dilution is provided by some 40 inches of rainfall that enters the soil annually. Therefore, new values have been computed that reflect the salinity and sodium hazard of effluent plus effective rainfall. Two levels of irrigation--20 and 40 inches per year--were assumed.

Table 1. --FACTORS AFFECTING THE SUITABILITY OF KRAFT MILL EFFLUENTS FOR IRRIGATION

Water	Conductivity	Sodium hazard	Biochemical oxygen demand	Residual sodium carbonate
	Micromhos/cm.	SAR 1/	Ppm.	Meq./l
Wash	1,275	6	60	0
80 percent wash 20 percent black	2,419	8	68	0
Black	6,990	15	102	0
Impounded	1,776	6	55	0

1/ Sodium adsorption ratio

As shown in Figure 1, 20 inches of wash water or 20 inches of the impounded water from the north Louisiana mill may be used annually for irrigation on most soils. At this level, the mixture of 20 percent black water and 80 percent wash water should be applied only to well-drained soils where salinity is controlled by flushing.

At the 40-inch level of application, wash water is relatively safe. The other two waters can be used only if soils are leached periodically to reduce the accumulation of soluble salts.

Small Pot Study

Phytotoxicity of effluents to 1- and 2-year-old slash pines was determined by irrigating seedlings growing in 2-gallon pots of sandy loam soil with various mixtures of wash and black waters from the central Louisiana mill. Seedlings were kept under a rainshelter where they received only prescribed waters.

Study effluents contained 0, 10, 20, 40, 80, and 100 percent black water plus complementary percentages of wash water. Well water served as a control. The evaluation began in July 1960, when the plants were about 3 months old and averaged 4 inches tall. Twenty-five inches of study waters were supplied in the first and 44 inches in the second growing seasons. During the winter the plants were irrigated with well water.

Seedlings in all pots grew well through October of the first year. However, in later November, those receiving 80 and 100 percent black water began to die. This mortality, caused by the residual salts, continued through the winter even though additional effluents were not applied. By April 1961, nearly all trees treated with 80 and 100 percent black water had died (Table 2). Mortality averaged 16 percent in plants treated with the 40 percent black water. Lesser concentrations did not affect survival of the yearling seedlings. Mortality continued through the second summer, and by the end of the growing season all seedlings receiving 40 percent or more of black water had died. The treatment with 20 percent black water killed

18 percent of the trees.

Table 2.--SURVIVAL OF SEEDLINGS AFTER THE FIRST AND SECOND YEAR IN THE SMALL-POT STUDY

Treatment	April 1961	December 1961
	-----------Percent-----------	
Well water	100	100
100 percent wash water	100	100
10 percent black, 90 percent wash water	100	100
20 percent black, 80 percent wash water	100	80
40 percent black, 60 percent wash water	84	0
80 percent black, 20 percent wash water	22	0
100 percent black water	10	0

It must be remembered at this point that the latter effluent has about maximum salinity and sodium hazards for an acceptable irrigation water. Its potential, however, anticipates application to a well-drained soil, plus leaching and other practices to control salt accumulation. These procedures were purposely omitted in this study.

Survival of one-year-old seedlings was related to the accumulation of sodium and soluble salts in the soil. These constituents increased directly with the amounts of black water (Table 3) and reached a lethal level with the 80 and 100 percent treatments. Soils in these pots contained 2200 to 2500 ppm. of sodium and 0.32 to 0.34 percent soluble salts. Their pH was 9.4.

Treatments had no effect on growth of the surviving seedlings. In other words, mortality was not preceded by stunting, and plants grew quite normally until definite concentrations of salts were reached. Survivors averaged 6 inches in height after one growing season and 14 inches after two.

Soils treated with 80 and 100 percent black water developed poor structure in the first year. This was primarily due to the combination of high sodium and organic residues in the black water. The surfaces of these soils were soupy when watered and rock-hard when dry. Soils receiving lesser amounts of black water were unpuddled and friable. In the second season, conditions originally observed in pots irrigated with high proportions of black water gradually developed in those receiving lower concentrations.

Table 3.--ANALYSES OF SOILS IN SMALL-POT STUDY AFTER ONE YEAR OF TREATMENT

Treatment	pH	Soluble salts	Sodium
		Percent	Ppm.
Well water	6.6	0.0100	60
100 percent wash water	7.0	.0200	164
10 percent black, 90 percent wash water	8.1	.0445	680
20 percent black, 80 percent wash water	8.6	.0615	855
40 percent black, 60 percent wash water	9.2	.1440	1,512
80 percent black, 20 percent wash water	9.4	.3425	2,480
100 percent black water	9.4	.3230	2,238

The treatments that caused the mortality and soil deterioration in this experiment were extreme. Soils were saturated with mill waters weekly, the effluents were usually stronger than those normally released by a mill, rainfall was excluded, and no leaching of the salt accumulation occurred. Under these circumstances, all pots receiving mill waters would eventually accumulate toxic amounts of salts and organic residues.

Soil Cores in Barrels

Irrigation under field conditions is more nearly simulated in a study where normal rainfall is supplemented with annual applications of 20 to 40 inches of effluents during the growing season. The objectives of this experiment are to determine the long-range effects of paper mill waste waters on slash pine survival and growth and on soil chemical and physical properties.

Seedlings are growing in undisturbed cores of a heavy, very slowly permeable soil. The cores are held in open-ended, 55-gallon drums. They were obtained by trenching around three sides of a block of soil and then fitting the drums over the cores by hand digging and driving. When a core was about 6 inches below the top of the drum a steel plate was forced under the bottom with a hydraulic jack. The encased cores were then transported to the study site and set on a subsoil layer similar in texture to that in the drums. The base plates were removed. A crib was then built around the drums and filled with sawdust to insulate them from wide variations in temperature.

Five effluent waters are being studied: the wash and impounded waters already described, plus mixtures of black and wash water which contain 10 and 20 percent of the stronger waste. An irrigated check is watered with well water; an unirrigated treatment receives only rainfall.

In January 1960, three one-year-old seedlings were planted in each drum. They were thinned to one per drum after the first growing season. Irrigation was started in April and has been continued each summer for 4 years. Thus, approximately 80 and 160 inches of effluents have been added to the soil during this period.

For 3 years, survival was unaffected by irrigation, but during the fourth year, several trees died due to the direct or indirect effects of the watering schedule. Losses were confined to the black water treatments. However, even here, survival was 67 percent where 40 inches of a 20 percent black water-80 percent wash water mixture was applied, and 70 percent where 20 inches of the same mixture was used (Table 4).

Table 4.--SURVIVAL AND HEIGHT OF SEEDLINGS IN 55-GALLON DRUMS AFTER 4 YEARS OF IRRIGATION

Kind of water	Amount	Survival	Height of survivors
	Inches	Percent	Feet
Rainfall only		100	5.7
Well water	20	100	5.0
	40	100	3.4
Wash water	20	100	5.7
	40	100	4.7
10 percent black, 90 percent wash water	20	100	4.2
	40	80	4.2
20 percent black, 80 percent wash water	20	70	3.9
	40	67	3.5
Impounded water	20	100	4.9
	40	100	4.2

The only other mortality occurred in the 40-inch level of the 10 percent black water-90 percent wash water treatment, where fourth year survival was 80 percent.

Growth has been influenced by the irrigation treatments almost from the beginning. In general, 20 inches of supplemental water has been superior to 40, and black water has been detrimental. But none of the treatments have increased growth over the unirrigated check. This is probably because many irrigated cores in drums were waterlogged during the growing season, or because serious moisture deficiencies did not develop in the unirrigated drums during periods of vigorous growth.

So far average heights of surviving trees have been considered, but neither variations within treatments nor explored factors which contributed to them have been mentioned. In some treatments, current heights of individual trees range from about 2 to more than 6 feet. Part of the variation is due to differences in the drainage rates of the cores. Although considerable care was taken in lifting to secure uniform soil, it was difficult, if not impossible, to prevent water seepage between the soil and the drums. Decaying roots and animal burrows have also increased percolation of the water through the cores. Conversely, certain of the effluents have tended to reduce infiltration. Water now stands continuously in 11 of the 110 cores. Of these 11, 9 receive mixtures of black and wash water and contain unusually short or dead trees. Cores receiving well water, wash water alone, and rainfall only are still relatively fast drainers and vary less in tree heights than their black water counterparts. This effect of black water on infiltration parallels results of the small pot study, where sodium or organic components of the effluent, or a combination of the two, degraded the soil to such an extent that it became a soggy mass when wet and a hard impermeable block when dry.

As in the small pot study, plants have been subjected to a severe test. Even when it was known beforehand that certain of the waters required extreme care in their application, they were puposely used without any treatment that would reduce their effects. Moreover, the soil in which the trees were planted is a member of the Caddo series, characterized by its impermeability and lack of drainage. With a better-drained, coarser-textured soil, it is quite possible that irrigation would have boosted growth over that achieved by rainfall alone.

Summary and Conclusions

In summary, the factors that limit suitability of water for irrigation are well established. They are sodium hazard, salinity hazard, concentration of bicarbonates, pH, and organic content.

Wash water and other kraft mill effluents that contain low concentrations of sodium and other soluble salts and have a B. O. D. of less than 2,000 to 5,000 ppm are suitable for irrigating pine trees--especially if they are applied to well-drained soils, and if special precautions are taken to prevent toxic accumulations of salt. Stronger wastes are undesirable irrigation waters because they leave in the soil organic and inorganic residues that depress growth and eventually kill trees.

No increase in growth of slash pine has been obtained by irrigating a very slowly permeable soil with 20 and 40 inches of effluent during the growing season. But growth stimulation may not be necessary for irrigation of forest land to be an attractive method of disposing of mill effluents. Growing plants transpire considerable quantities of water, and thus increase the amount of liquid that can be disposed of by land application. This, coupled with the public goodwill that results from eliminating effluents from streams, may more than offset a moderate expenditure for an irrigation system.

Permissible amounts and concentrations of effluents must be worked out locally by individual mills. Application will depend on soil texture, infiltration rate, and precautions needed to prevent the accumulation of excessive amounts of soil salts.

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