DISPOSAL OF SUGAR REFINING LAGOON EFFLUENTS ON FARGO SILTY CLAY SOIL

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Processing of sugar beets requires large amounts of water for transporting and washing beets, for cooling and other uses. In addition, the beets themselves yield some 80 per cent of their weight in water. All of these waters become polluted in the manufacturing process and represent a disposal problem. This is particularly true in a cold climate in which biological activity, necessary to reduce the pollution levels, is low for much of the year.

The current practice in the Red River Valley area of North Dakota and Minnesota is to pond these wastes in large lagoons and release them at the time of the spring flush of the rivers. Under proposed federal and state pollution standards this method of disposal will not be possible. The industry is testing ways to minimize the water requirements in their plants, and other processing modifications, but a disposal problem will still exist.

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One method of disposing of sugar processing wastes is by spray application over soil (1). As the polluted water percolates through soil it becomes purified, a result of both mechanical filtration and biological action of the soil microflora on the pollutants in the water. The speed with which water can be disposed in soil depends upon the soil type. A sandy soil allows very rapid infiltration rates but rates through clayey soils tend to be slow.

Infiltration rates

Fargo silty clay is the dominant soil found in the Red River Valley (Lake Agassiz basin). The tests reported here were conducted on soils in galvanized metal sleeves about eight inches in diameter and 22 inches long. These sleeves were hydraulically pressed into the soil and when dug out contained an essentially undisturbed column of the soil. A vacuum may be applied at the bottom of the columns to simulate the suction of a natural subsoil.

The rate of infiltration of the effluent waters from the sugar processing storage lagoons through Fargo silty clay was found to be very low. One column of soil allowed passage of only 433 ml in seven and one half days and another only 83 ml. These figures represent about 0.5 and 0.1 inches of water respectively. There was no evidence from

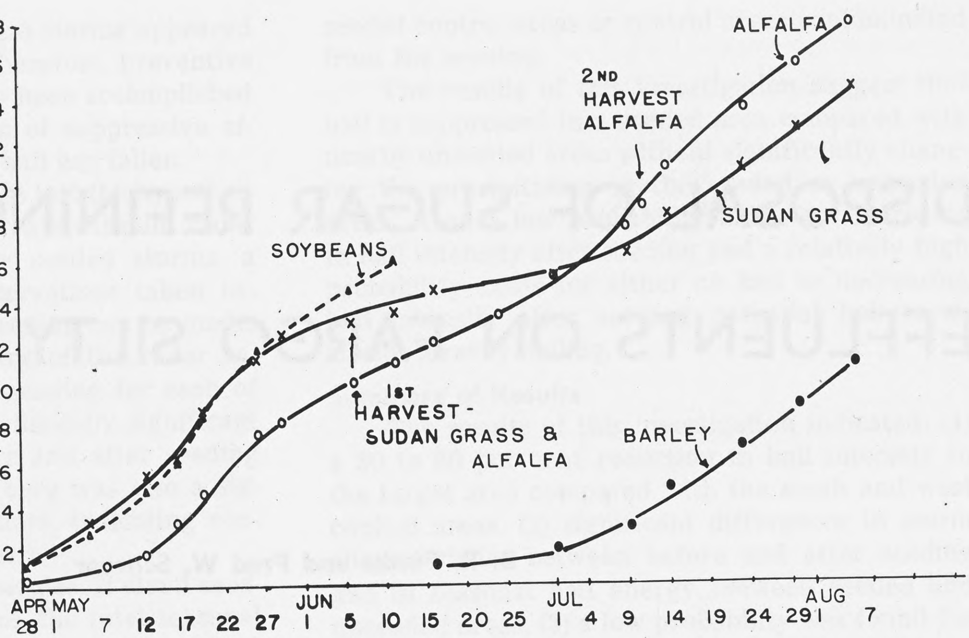

Fig. 1. Comparative evaporation by soybeans, sudan grass (two crops), alfalfa (three crops), and barley.

these experiments that the effluents were causing any soil clogging as compared to distilled water. These results indicate that disposal of such wastes on this soil type will have to depend largely upon evaporation and transpiration into the atmosphere rather than percolation to the water table.

Transpiration rates

The columns of the Fargo silty clay were planted with alfalfa, soybeans, sudan grass and barley in sets of eight. Four replicates of each plant type in the experiments were supplied to the capacity of the soil with distilled water. The other four replicates received effluents from the lagoon of the American Crystal Sugar Company plant in Moorhead, Minnesota. Temperatures and relative humidity in the greenhouse were automatically recorded. Temperatures usually dropped to a minimum of 70 degrees at night. Daily highs in the 80's were recorded. Some daily temperatures ranged into the 90's. Relative humidity varied widely with the day and the season. Nighttime humidity levels commonly fell into the 30-50 per cent range and day readings were in the 50-90 per cent range.

Transpiration amounts from these experiments are shown in Figure 1. The experiments continued from April 28 through August 5, 1969. Three successive crops of alfalfa and two successive crops of sudan grass were harvested. The soybeans were harvested June 11 and the same were seeded with barley, which was harvested at the close of the experimental period, August 5. Alfalfa, for the period of the first crop, transpired less water than soybeans and sudan grass. However, alfalfa has an advantage over soybeans in the ability to be almost continuously cropped, and over sudan grass in economic return. Barley was not a very efficient plant for water transpiration.

Effect of lagoon wastes on plant growth

The average dry weights of individual plants which received, respectively, lagoon effluents and distilled water are listed in Table 1. The plants receiving lagoon effluents were in no case smaller than the controls receiving distilled water. In the case of barley and the second cropping of sudan

Table 1. Plant Weights: Distilled Water Treatment vs. Effluent.

Plant	Number of plants		Average dry weight of plant (grams)	
	Water	Effluents	Water	Effluents
Alfalfa				
First harvest	38	39	1.27	1.38
Second harvest	38	39	1.75	2.11
Third harvest	30	32	1.78	1.62
Sudan grass				
First harvest	65	67	2.54	2.46
Second harvest	46	47	1.80	2.34
Barley				
First harvest	56	56	0.62	0.99
Soybeans				
First harvest	20	20	7.58	7.32

grass the plants were visibly larger and weighed more when watered with lagoon effluents. See photo, Figure 2.

Effects of lagoon effluents on Fargo silty clay

Table 2 summarizes some of the data comparing Fargo silty clay to which lagoon effluents had been applied with samples to which distilled water had been applied. The carbon-nitrogen ratio was not significantly altered by addition of effluents. This ratio did not exceed 13:1, which is below the level at which nitrogen would be immobilized in forms unavailable for plants. The soil became more alkaline, the pH changing from 6.5 to about 7.5, which is still within an acceptable range.

There was an increase in soil salinity as indicated by the increased electrical conductivity of water extracts (ECE) from soils treated with the effluent. These higher salinities with effluent are still within the range that we might find in normal Fargo silty clays in our fields and would not be harmful to the crops normally grown here. Long time application of these effluents that contain salts indicated by conductivity values of about 1.0 millimho (a unit of conductivity) (Table 3) would likely cause further increases in salinity of this slowly permeable soil (2).

A total of 28 liters of effluents was applied to the alfalfa. By calculation this amount of effluent should produce a salinity of 0.84 millimhos in a saturated extract, assuming that all the salts remain in the soil column and are extracted. Actual concentrations found in the upper nine inches of soil columns were about 0.6 millimhos. The deficit from an estimated 0.84 millimhos can be attributed

Fig. 2. Barley plants at left received effluent only, plants at right received distilled water only.

to precipitation of the lesser soluble calcium salts and to nutrient removal by the alfalfa. Sodium content of the soil extracts is of interest because a high proportion of sodium can cause reduced soil permeability and poor soil structure. Extractable sodium was higher in effluent-treated than in water-treated soils. The amounts found were about 2.0 milliequivalents per liter for the effluent and

Table 2. Analysis of Fargo Silty Clay Following Application of Distilled Water and Sugar Refining Lagoon Effluents.

Crop & Treatment	Total C	Total N	C:N ratio	pH	ECE* (25°C)	Ca (Milli-equivalents per liter of extract)	Mg	Na	K	NO_3-N (ppm)	P ppm
Sampling depth, 0-3 inches. Figures are average of four replicates											
Alfalfa (water)	4.96	.401	12.4:1	6.4	0.35	1.5	2.2	0.47	0.21	1.9	25
Alfalfa (effluents)	4.86	.381	12.8:1	7.3	0.66	2.1	3.1	2.0	0.31	3.4	35
Soybean - Barley**(water)	4.90	.389	12.4:1	6.6	0.32	1.2	1.8	0.45	0.21	4.6	21
Soybean-Barley (effluents)	4.91	.385	12.8:1	7.5	0.66	1.9	2.6	2.2	0.27	3.9	28
Sudan grass (water)	5.02	.384	12.1:1	6.7	0.48	2.0	2.8	0.56	0.19	1.5	23
Sudan grass (effluents)	5.09	.398	12.8:1	7.4	0.73	2.4	3.3	2.2	0.37	2.2	20
Sampling depth, 3-9 inches. Figures are average for four replicates.											
Alfalfa (water)		(Not tested)		6.4	0.38	1.6	2.4	0.70	0.15	1.6	20
Alfalfa (effluents)	"	"	"	6.8	0.62	2.2	3.6	1.5	0.19	2.4	26
Soybean-Barley (water)	"	"	"	6.6	0.36	1.3	2.0	0.60	0.15	3.0	18
Soybean-Barley (effluents)	"	"	"	7.1	0.63	2.1	3.1	1.4	0.18	2.8	19
Sudan grass (water)	"	"	"	6.6	0.47	2.0	2.8	0.69	0.19	1.3	21
Sudan grass (effluents)	"	"	"	7.1	0.66	2.4	3.5	1.5	0.23	2.3	23

*Electrical conductivity of the saturation extract
**Soybean crop was followed by barley in the same soil column

Table 3. Analyses of Sugar Refining Lagoon Effluents.

Sample date		pH	Conductivity (mmhos)	Ca (Milli-equiv. per liter)	Mg	Na	K	NO_3-N (ppm)	COD mg/l	BOD mg/l
April	28	6.5	1.28	6.2	4.7	1.8	1.3	1.9	904	1329
May	5	7.1	1.37	7.3	5.2	1.9	1.2	1.7	630	1080
	12	7.8	0.96	2.9	5.3	1.9	1.2	1.9	684	1260
	15	7.8	0.94	2.7	5.2	2.0	1.2	1.5	465	590
	19	7.9	0.97	2.7	5.4	2.0	1.2	2.4	359	580
June	3	7.6	1.30						355	445
	9	8.2	1.04			(Not determined)			311	457
	16	8.0	1.04						326	263
	24	8.1	0.97						324	236
July	1	7.3	1.02	4.3	5.9	2.0	1.2	5	272	158
	8	8.2	1.11	4.0	6.3	2.2	1.3	11	251	140
	14	7.8	1.21	3.4	6.4	2.1	1.4	12	160	41
	23	7.6	0.98	2.8	5.5	1.7	1.2	14	61	17
	30	8.4	0.89	2.1	4.8	2.0	1.3	16	52	1

about 0.5 for the distilled water. Estimates of exchangeable sodium percentage made from extractable sodium (2) in the effluent treated soils yield figures of about 0.5 per cent. This sodium percentage would have a negligible effect on soil structure and permeability. The equilibrium exchangeable sodium percentage that would be predicted from effluent composition is 0.4. The close agreement to the figure obtained from soil extracts indicates that the soil is approaching a balance with the effluent. Further increase in ESP could be expected from use of additional effluent because leaching of sodium salts through the profile is probably very low in this soil.

Nitrate nitrogen levels were low, about normal for this soil directly following cropping. There seemed to be no consistent difference in nitrate levels between soils receiving effluents or distilled water. Phosphorus levels were slightly higher in samples receiving effluent.

Analyses of Lagoon Water

Periodic analysis (Table 3) of the lagoon effluent showed little variation in the electrical conductivity, magnesium, sodium, and potassium levels. The effluent became more alkaline, as indicated by the increase in pH from 6.5 to 8.4 from April through July. Nitrate nitrogen increased from 1.9 ppm in April to 16 ppm at the end of July, probably reflecting nitrification under more aerobic conditions in the lagoon. The calcium level decreased during the course of the experimental period, probably a seasonal effect of increasing temperature. The Biochemical Oxygen Demand (BOD) declined from 1329 mg/liter at the beginning to an insignificant figure on July 30. Biochemical Oxygen Demand is a measure of dissolved organic matter in waters. As organic matter is utilized by microorganisms the dissolved oxygen is depleted. Loss of dissolved oxygen in streams leads to undesirable changes such as odors and death of fish.

Chemical Oxygen Demand (COD) also showed a steady decline during the experimental period. Chemical Oxygen Demand is a measure of biologically degradable compounds contained in the water as in BOD, as well as those which are not.

Conclusions

It should be possible to dispose of appreciable volumes of sugar refining wastes by spray application to cropped Fargo silty clays. No short term, one season, deleterious effects were noted on either the soil or on the plants cropped. Of the plants tested, alfalfa seems to be the most suitable. The sodium level in soils receiving these effluents should be checked carefully to see if the increase noted in these experiments continues to undesirable levels.

Certain problems not encountered in the greenhouse could complicate disposal of lagoon effluents on the Fargo soil:

1. Infiltration into a moist or wet Fargo silty clay would be much slower than into the dry cracked soil we had in the experiment. This soil absorbs water rapidly through surface cracks that form on drying.
2. Surface ponding and loss of stands could occur in eastern North Dakota because of heavy showers that may come during, or just after, a soaking with effluent.
3. Growing season precipitation, in some years, is more than adequate to meet evapotranspiration demands, and little or no effluent could be used.

Field tests are being planned.

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