Irrigating with Sugarbeet Processing Wastewater*

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INTRODUCTION

In recent years, irrigating agricultural land with wastewater has become a major wastewater management practice. Irrigation has replaced much of the discharge to streams and conventional primary and secondary waste treatment for food processing wastewater (4, 11, 12, 13). Irrigating agricultural land for treatment and disposal of the food processing wastewater is a good practice if the wastewater does not contain toxic constituents. Crops grown on the land remove part of the plant nutrients supplied by the wastewater and can be fed to livestock (1, 2).

Considerable information has been published about wastewater irrigation in recent years and several food processing wastewaters have been evaluated for irrigation use (5, 6, 17, 18, 19). These systems work well, oxygen demand and the chemical constituents, except potassium, were satisfactorily removed at moderate applications, as wastewater passed through the soil, and using wastewater for irrigation can economically benefit users.

Nutrient concentrations in wastewaters, and in some cases feasibility for irrigation use, have been evaluated for several food processing wastewaters: cannery wastes (8, 16), citrus wastes (10), vegetable wastes (14, 21, 22, 23), fruit processing wastes (15, 21, 22, 25), and grain wastes (22). For the most part these wastewaters can be used for irrigating agricultural land with a minimum of problems.

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Sugarbeet processors discharge large volumes of wastewater containing relatively low concentrations of organic matter, suspended solids, and various inorganic nutrients. As a result, large amounts of nitrogen and organic matter can be applied to the fields.

The objectives of this paper are to 1) summarize data for flood irrigation with sugarbeet processing wastewater, 2) evaluate soil loading with nutrients and organic matter, 3) examine water cleanup through soil filtration and microbiological activity, 4) observe some aspects of nutrient utilization, 5) consider salinity and specific ions in the soil, and 6) discuss feasibility of continued irrigation with sugarbeet processing wastewater.

METHODS AND MATERIALS

This study was conducted at Amalgamated Sugar Company plants located at Twin Falls, Rupert, and Nampa, Idaho where wastewater is being used to irrigate cropped fields. The wastewater irrigation fields were designed and prepared for wastewater irrigation by grading to rigid specifications for surface irrigation and diking the fields to prevent runoff. The fields seeded to an orchard grass *(Dactylis glomerata)* and alfalfa *(Medicago sativa)* mixture were harvested for hay during the summer growing season. Wastewater was sampled at each sugarbeet processing plant twice weekly during the sugarbeet processing season, which began in October and ran for 100 or more days. An automatic sampler delivered wastewater into a freezer at designated intervals, where it was frozen in a plastic container and stored until analyzed (7). At the Nampa plant, a water meter was installed that actuated the sampler at preset water volumes, sampling the wastewater in proportion to the volume passing through the meter.

Wastewater irrigations were scheduled at 1, 2, and 4 week intervals at the Twin Falls and Rupert sites and at 2 and

4 week intervals at the Nampa site. The weekly irrigations were stopped in January because the plots were severely overloaded. Soil water was sampled after each irrigation, using 3.8-cm-diameter poly-vinyl-chloride sampling tubes with porous ceramic cups cemented to one end. Duplicate sets of sampling tubes were inserted vertically into the soil to depths of 15, 30, 60, 90, 120, and 150 cm at each sampling site. When taking samples approximately 0.7 bar suction was applied to the tubes for about 48 hours. The extracted water was pumped into a suction flask, transferred to a plastic bottle, and refrigerated in the laboratory until analyzed. Not every tube yielded a water sample at every sampling.

The water samples were analyzed for COD (3) and nitrate-nitrogen was determined with a nitrate-specific ion electrode. Total nitrogen was determined by a Kjeldahl procedure, modified by substitution of copper for the mercury catalyst (3). Total phosphorus was determined by persulfate oxidation (24) and potassium, by flame photometry. Water applications to the fields were measured by the field operators using water meters. Processing plant waste effluents, water samples extracted with extraction tubes, and saturated soil extracts were also analyzed for sodium by flame photometry; calcium and magnesium by atomic absorption spectrometry; chloride, by silver titration; sulfate, by precipitation as barium sulfate and measurement on a spectrophotometer; total dissolved salts, by electrical conductivity, and pH. Soils sampled annually were analyzed for the above constituents and for total organic matter by wet digestion. The first samples were analyzed for cation exchange capacity (CEC) and particle size distribution from each sampling depth. The soil classification at the Twin Falls sites was silt loam from the surface to 150 cm depth. At Rupert the soils were sandy loams to loams, and at Nampa the soils were clay loams to loams in the surface and sandy loams to loams at 150 cm depth. For complete soil analyses see Smith and Hayden (20).

Plant samples were taken in the fields periodically and analyzed for total nitrogen by a Kjeldahl procedure and for nitrate, phosphorus, and potassium.

RESULTS AND DISCUSSION

Wastewater applications at the fields were at planned rates of 10 cm per irrigation and initially scheduled at 1 (A), 2 (B), or 4 (C) week intervals. Irrigations as applied by the treatment field operators to dispose of the wastewater were designated (D). After the first irrigation season, we determined that the weekly irrigation schedule was excessive, and therefore this treatment was terminated and these plots were then irrigated according to schedule (D). Some wastewater irrigations at various schedules shown in Table 1 had applications ranging from 28 to 169 cm per sugarbeet processing season. For a complete listing of all wastewater irrigations see Smith and Hayden (20). The COD, nitrogen, phosphorus, and potassium applications in the same selected treatments reported for wastewater application are shown in Table 1. The weekly wastewater applications applied excessive amounts of COD, nitrogen, and potassium. The 140 metric tons of COD applied the first year at the Twin Falls site and the 61 tons at Rupert both damaged the vegetation because of anaerobic conditions associated with the high water and organic additions and the large amounts of nitrogen would be expected to pollute the soil and groundwater. Most other application rates were within an acceptable range and could be managed to utilize much of the added nutrients by cropping and removing the crops for utilization elsewhere. Phosphorus applications in most treatments except the weekly irrigations were lower than the annual phosphorus removal by crops. Soil tests need to be run occasionally to monitor phosphorus in the soil. Occasional phosphorus fertilization may be necessary to supplement wastewater applied phosphorus to maintain optimum fertility for growing hay crops.

Table 1. Annual wastewater, chemical oxygen demand (COD), nitrogen, phosphorus, and potassium applied to fields irrigated with sugarbeet processing wastewater.

Location (Irrigation schedule)	water applied cm	COD Ton /ha	Nitrogen	Phosphorus kg/ha	Potassium
Twin Falls					
(A)[a] weekly	155	139	4200	34	2820
(B) 2 weeks	87	46.5	1582	13	1005
(C) 4 weeks	48	22.3	860	7	630
(D)[b] 76-77	42	17.1	555	14	1095
(D) 77-78	169	46.9	1425	13	3405
Rupert					
(A) weekly	109	60.6	1150	16	430
(B) 2 weeks	48	28.0	570	8	195
(C) 4 weeks	28	15.1	335	5	130
(D) 76-77	50	10.0	335	11	510
(D) 77-78	28	8.1	370	13	490
Nampa					
(D) 76-77	116	10.4	277	15	3080
(D) 77-78	114	9.7	383	16	3410

[a] 1975-1976 Processing season.

[b] Represents average applications to entire field during processing season.

Potassium applications to the wastewater irrigation fields were mostly high to very high (Table 1). No potassium deficiencies would be expected in the crops grown on the treated fields. Also no problems should develop because potassium leaching equilibrium would be reached in a few irrigation seasons and the soil potassium concentrations should remain relatively constant.

COD concentrations in the wastewater varied widely with time and locations. At the Twin Falls and Nampa plants the wastewater was stored for a short time in ponds before being pumped to the fields. The storage ponds buffered changes in the COD concentration by mixing a large volume of plant effluents. Concentrated Steffen waste spilled into the Twin Falls pond early in the season. This raised the pond COD concentration to 8,000 mg COD/ liter. Before the high COD concentration was diluted by the lower concentration wastewater, large amounts of COD and other constituents were applied to the land. COD ranged from 2,000 to 8,200 mg/liter and the average in the Twin Falls wastewater for the second and third processing seasons was approximately 3,300 mg/liter. At the Rupert field, COD ranged from 1,500 to 5,300 and averaged 3,300 mg/liter for the three processing seasons. COD concentrations at the Nampa plant ranged from 345 to 2,000 and averaged 1,100 mg/liter for two processing seasons.

COD analyses for wastewater and for water samples extracted from the 150 cm depth in the fields are summarized in Table 2. At the Twin Falls wastewater irrigation fields, an average of 48% reduction was found for the three processing seasons for the 4-week irrigation schedule. At the Rupert fields, the wastewater COD averaged 3,450 and the soil water COD averaged 550 mg/liter for an 84% average reduction for three years. At the Nampa fields the wastewater averaged 1,050 and the soil water 268 mg/liter for a 75% average COD reduction. The highest soil water COD concentrations were observed during the processing seasons and the lowest in the summer. The fields were irrigated in the summer with canal water having almost no COD. Soil water analyses during the summers taken from the 150 cm depth averaged 98, 98, and 88% COD reduction from the average wastewater COD concentrations during the processing season at the Twin Falls, Rupert, and Nampa plants respectively. The COD cycle resulted from a decreased COD application following the processing season and biological decomposition of the added organic materials in the soil as well as leaching of the added organic materials. In some of the wastewater irrigation fields, the soil is deeper than 150 cm and the organic material cleanup by filtration and biological activity will continue as the water infiltrates deeper into the soil profile. This should ultimately produce a clean effluent.

Table 2. Chemical Oxygen Demand (COD) in sugarbeet processing wastewater, and in water extracted from 150 cm deep in the wastewater irrigation fields.

milligrams per liter

Location (Irrigation schedule)[a]	Soil Depth cm	Oct 1975	Nov 1975	Dec 1975	Jan 1976	Feb 1976	Mar 1976	Apr 1976	May 1976	June 1976	July 1976
Twin Falls	0	20	8215	5795	5200	5970	3275	2920	20	20	20
(A)	150	55	2040	4825	4200	4030	2795	1655	1380	1560	1375
(B)	150	30	45	3865	3580	-	2840	1710	-	1145	1050
(C)	150	75	2005	4620	3710	-	1945	1695	-	495	70

		Nov 1976	Dec 1976	Jan 1977	Feb 1977	Mar 1977	July 1977	Nov 1977	Dec 1977	Apr 1978	July 1978
	0	2955	4850	3830	3600	1995	20	3070	2915	20	20
(A)	150	1090	585	230	305	1030	130	-	605	610	185
(B)	150	580	2195	2605	1975	1590	125	1160	-	400	85
(C)	150	2150	3565	2520	1730	1540	80	1525	1430	360	115

		Oct 1975	Nov 1975	Dec 1975	Jan 1976	Feb 1976	Apr 1976	Aug 1976	Oct 1976	Nov 1976	Dec 1976
Rupert	0	5050	6295	5240	4523	6010	20	15	2595	1995	1530
(A)	150	50	215	360	840	845	255	100	300	1010	1410
(B)	150	270	615	620	690	-	345	55	215	2425	840
(C)	150	35	50	80	65	-	60	50	850	2155	1085

		Jan 1977	Apr 1977	July 1977	Sep 1977	Oct 1977	Dec 1977	May 1978	July 1978
	0	1915	30	20	20	-	2935	540	25
(A)	150	-	75	45	20	-	-	125	105
(B)	150	245	85	45	40	640	610	240	95
(C)	150	590	160	50	40	620	585	120	125

		Oct 1976	Nov 1976	Dec 1976	Jan 1977	Mar 1977	July 1977	Nov 1977	Dec 1977	Mar 1977	May 1977
Nampa	0	1230	1990	1845	2310	625	15	1215	1110	636	853
(B)	150	20	40	55	665	405	45	70	195	90	135
(C)	150	615	375	990	335	300	120	90	75	190	90

[a] See text for irrigation schedules.

Nitrogen concentrations in wastewater and in water extracted from the 150 cm depth in the wastewater irrigation fields are reported in Table 3. High total nitrogen was found in the wastewater samples from the Twin Falls plant that corresponded to high COD concentrations early in the project. The average total N for the first season was 210 and for three seasons was 132 mg/liter. The average total N remaining in the water extracted from the 150 cm depth was 4 mg/liter which represented a 97% decrease with passage through 150 cm of soil. Average

Table 3. Total Nitrogen in sugarbeet processing wastewater and in water extracted from 150 cm deep in wastewater irrigation fields

Location (Irrigation schedule)[a]	Soil Depth cm	milligrams per liter									
			1975		1976						
		Oct	Nov	Dec	Jan	Mar	Apr	May	June	July	Nov
Twin Falls	0	-	682	202	134	72	44	1	1	1	93
(A)	150	1.6	48	172	146	64	-	97	89	2	42
(B)	150	1.4	2	90	72	57	32	-	8	3	7
(C)	150	1.6	76	131	64	82	52	-	6	4	4
			1977								
		Dec	Jan	Feb	Mar	June	July	Sep	Nov	Dec	
	0	148	120	90	53	1	2	0	83	99	
(A)	150	69	-	-	4	7	5	5	-	12	
(B)	150	6	-	-	-	-	-	-	-	-	
(C)	150	-	22	15	15	-	-	-	30	50	
		1975			1976						
		Oct	Nov	Dec	Jan	Feb	Apr	June	Aug	Oct	Nov
Rupert	0	1	136	84	84	55	2	1	1	79	60
(A)	150	2	2	2	2	2	5	3	4	2	2
(B)	150	3	2	3	3	-	4	2	3	2	2
(C)	150	1	2	3	1	-	3	2	1	2	4
			1977							1978	
		Dec	Jan	Apr	June	July	Sep	Oct	Dec	July	Aug
	0	76	61	1	1	1	7	78	59	1	1
(A)	150	2	-	2	2	2	2	-	-	22	2
(B)	150	3	-	3	2	2	2	-	-	12	13
(C)	150	2	3	2	2	2	2	7	4	5	4
			1976		1977					1978	
		Oct	Nov	Dec	Jan	Mar	July	Nov	Dec	Mar	May
Nampa	0	47	54	54	54	15	-	56	78	16	16
(B)	150	2	1	1	1	1	1	1	1	1	1
(C)	150	2	1	2	-	-	1	1	1	1	1

[a]See text for irrigation schedules.

total N for three seasons at Rupert was 75 mg/liter and average soil water N was 2.4 mg/liter at the 150 cm depth, which represented a 98% decrease. The average total N in the wastewater at Nampa was 36 mg/liter, and average soil water N at the 150 cm depth was 4 mg N/liter. This represents an 88% decrease from the wastewater total N concentration.

Nitrate-N in the wastewater at the three wastewater irrigation fields was low with < 1 mg/liter at the three locations. Organic N is converted to NO_3 when the

organic matter in the wastewater is decomposed. The nitrate concentration in the soil water was occasionally high. Water in the Twin Falls fields ranged from 0 to 167 and averaged 17 mg NO_3-N/liter. By removing three high nitrate values from the total before averaging the concentrations, the mean of the remaining values was 8.7 mg NO_3-N/liter. Many soil water samples had NO_3-N concentrations below 1 mg/liter. The nitrate concentrations at Rupert were considerably lower than at Twin Falls with a range of 0 to 13 and an average concentration of 2.3 mg NO_3-N/liter. Nitrate concentrations at Nampa were intermediate with a range of 0 to 30 and an average of 7.8 mg NO_3-N/liter (Table 4).

Phosphorus concentrations in the wastewater were low, which resulted in relatively small applications of phosphorus. The normal irrigation rates for the three fields would not maintain the fields at adequate phosphorus levels. Phosphorus in the sugarbeet processing wastewater at Twin Falls averaged 1.9 and ranged from .8 to 4.1 mg/liter. At Rupert the P concentration averaged 1.8 and ranged from .7 to 4.3 mg/liter. At Nampa the P concentration averaged 1.7 and ranged from .3 to 2.9 mg/liter. The average concentration at the 150 cm soil depth was .19, .12, and .62 mg/ liter for the Twin Falls, Rupert, and Nampa sites, respectively (Table 5). These low phosphorus concentrations should minimize P leaching through the soil. The higher P concentration in the soil water at the Nampa site compared to the other two sites is probably associated with soil differences and is not directly related to phosphorus concentrations in the wastewater.

Potassium applications on the wastewater irrigation fields were high to very high. The lowest potassium concentrations and applications were found at the Rupert fields with intermediate values at Twin Falls and the highest at Nampa.

Table 4. Nitrate-Nitrogen in sugarbeet processing wastewater and in water extracted from 150 cm deep in wastewater irrigation fields

Location (Irrigation schedule)[a]	Soil Depth cm	milligrams per liter									
			1975		1976						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	June	July	
Twin Falls	0	-	2.0	1.0	0.5	0.6	1.4	1.5	0	0.1	
(A)	150	1.8	8.6	1.4	0.4	0.5	0.3	0.3	0.8	0.5	
(B)	150	23.3	8.7	2.4	0.4	-	2.7	0.5	2.3	5.9	
(C)	150	25.1	12.2	0.3	0.5	-	0.2	3.6	0.6	49.0	
				1977						1978	
		Nov	Dec	Jan	Feb	Mar	July	Nov	Dec	Apr	July
	0	0.4	0.5	0.6	0	0	0	0	0	0.1	0
(A)	150	35.2		68.6		50.0	43.6	-	2.9	-	0.4
(B)	150	140.5	4.4	1.3	-	0	38.5	-	-	0	-
(C)	150	8.5	0.6	0.3	0	0.6	10.4	0	1.8	-	34.4
		1975			1976						
		Oct	Nov	Dec	Jan	Feb	Apr	July	Oct	Nov	Dec
Rupert	0	1.0	1.1	1.5	1.6	1.0	0	1.1	0.6	0.8	0.4
(A)	150	10.2	5.2	0.6	0.2	0.4	3.5	1.0	0.9	1.4	0.1
(B)	150	13.8	0.8	0.6	0.1	-	3.2	0.4	0.2	0.2	0.2
(C)	150	12.8	10.6	10.3	10.2	-	0.1	0.9	1.0	0.2	0.5
		1977						1978			
		Jan	Apr	June	July	Oct	Dec	May	July	Aug	
	0	0.1	0.4	0.1	0	0.1	0	0.4	0.2	0.4	
(A)	150	-	0.4	16.9	1.0	-	-	0.6	3.2	7.3	
(B)	150	0.1	0.3	0	0.1	0.1	0	1.7	9.5	1.6	
(C)	150	0	2.6	0	-	0	0	0.4	0.9	-	
		1976			1977					1978	
		Oct	Nov	Dec	Jan	Mar	July	Nov	Dec	Mar	May
Nampa	0	1.4	1.8	1.6	0.3	0.2	-	0	0	1.7	2.4
(B)	150	9.0	3.6	5.3	0.5	1.1	23.6	12.2	1.8	3.4	5.1
(C)	150	9.0	17.3	1.7	4.5	1.0	23.6	0	0	1.9	2.2

[a]See text for irrigation schedule.

Potassium concentration in the wastewater at Twin Falls averaged 5.6 and ranged from 1.1 to 13.2 meq K/ liter. At Rupert the average was 3.2 and ranged from 1.6 to 7.3 meq K/liter. At Nampa the average was 7.3 and ranged from 3.2 to 14.8 meq K/liter. Potassium concentrations in the soil water extracted from the 150 cm depth were 2.3, .21, and .21 meq K/liter for Twin Falls, Rupert, and Nampa respectively (Table 6).

A large amount of K is being applied to these wastewater irrigation fields and varying amounts are being leached

Table 5. Total phosphorus in sugarbeet processing wastewater and in water extracted from 150 cm deep in the wastewater irrigation fields

Location (Irrigation schedule)[a]	Soil Depth cm	milligrams per liter									
			1975		1976						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
Twin Falls	0	-	.85	1.23	1.21	2.08	2.00	1.10	.23	.05	.18
(A)	150	.09	.05	.10	.08	.07	.16	.55	.57	.43	.26
(B)	150	.05	.08	.10	.05	-	.15	.07	-	.15	.25
(C)	150	.06	.07	.04	.05	-	.16	.08	-	.09	.16
				1977						1978	
		Nov	Dec	Jan	Feb	Mar	July	Nov	Dec	Apr	July
	0	2.08	3.84	4.06	-	1.02	.16	2.31	3.10	.79	.26
(A)	150	.22	.12	.06	-	-	.56	.14	.16	-	.22
(B)	150	.08	.16	.08	-	-	-	.13	-	-	-
(C)	150	.06	.06	.12	.08	.08	.11	.12	.14	-	.06
		1975			1976						
		Oct	Nov	Dec	Jan	Feb	Apr	Aug	Oct	Nov	Dec
Rupert	0	1.23	1.37	2.08	1.90	.68	.47	.10	1.71	1.67	2.61
(A)	150	.07	.02	.02	.04	.07	.16	.50	.08	.25	.38
(B)	150	.27	.10	.08	.06	-	.19	.11	.07	.14	.11
(C)	150	.04	.01	.03	.02	-	.12	.10	.05	.04	.48
		1977						1978			
		Jan	Apr	July	Sep	Oct	Dec	May	July		
	0	4.27	.02	.12	.75	2.59	2.28	.05	.10		
(A)	150	-	.06	.06	.06	-	-	.20	.08		
(B)	150	-	.12	.06	.04	.06	.12	.09	.26		
(C)	150	.04	.04	.12	.09	.06	.08	.08	.11		
		1976			1977					1978	
		Oct	Nov	Dec	Jan	Mar	July	Nov	Dec	Mar	May
Nampa	0	1.52	1.46	1.38	2.10	1.22	-	1.70	1.85	2.94	1.81
(B)	150	.24	.31	.44	.26	.17	.20	.15	.13	.19	.12
(C)	150	1.29	1.16	1.24	.96	.37	1.03	1.04	.90	.63	.81

[a]See text for irrigation schedule.

through the soil profile. A K equilibrium will probably be reached after a few years of wastewater irrigation in which the K leached from the fields will approximately equal that applied in the wastewater minus K used by crops.

Electrical conductivity (EC) and the associated salt in the wastewater is one of the general concerns about irrigating with sugarbeet processing wastewater. Table 7 gives the EC values for wastewater and soil water ex-

Table 6. Potassium in sugarbeet processing wastewater and in water extracted from 150 cm deep in the wastewater irrigation fields.

Location (Irrigation schedule)[a]	Soil Depth cm	milliequivalents per liter									
		1975		1976							
		Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Nov
Twin Falls	0	13.2	7.5	5.9	6.4	4.9	3.3	.02	.1	.1	5.4
(A)	150	2.1	6.8	4.2	4.6	6.0	3.3	.2	.4	.3	1.6
(B)	150	.1	4.8	2.9	-	4.8	3.9	-	.1	.2	2.6
(C)	150	1.4	4.7	3.0	-	4.2	3.4	-	.1	.1	.9
			1977							1978	
		Dec	Jan	Feb	Mar	May	July	Nov	Dec	Apr	July
	0	7.2	6.1	5.5	2.9	.1	.7	5.4	5.7	3.0	.1
(A)	150	3.8	1.7	-	3.5	.1	.4	4.0	2.8	-	-
(B)	150	2.7	3.5	-	2.1	-	3.2	2.7	2.1	3.8	-
(C)	150	2.2	1.7	1.6	1.5	1.2	1.2	3.3	2.9	-	2.7
		1975			1976						
		Oct	Nov	Dec	Jan	Feb	Apr	Aug	Oct	Nov	Dec
Rupert	0	5.25	2.3	7.3	1.61	2.9	.18	.18	1.61	1.75	3.23
(A)	150	.13	.13	.11	.06	.09	.10	.17	.14	.14	.07
(B)	150	.16	.15	.28	.11	-	.08	.18	.16	.18	.09
(C)	150	.06	.10	.10	.11	-	.06	.17	.13	.11	.02
		1977						1978			
		Jan	Apr	July	Sep	Oct	Dec	May	July	Aug	
	0	3.83	.15	.13	3.78	2.39	1.84	.89	.16	.14	
(A)	150	-	.10	.14	.17	-	-	.51	.62	.94	
(B)	150	-	.16	.24	.18	.32	.62	.74	.57	.56	
(C)	150	.10	.08	.07	.11	.16	.24	.30	.23	.24	
		1976			1977					1978	
		Oct	Nov	Dec	Jan	Mar	July	Nov	Dec	Mar	May
Nampa	0	6.82	4.32	7.39	6.61	3.84	-	3.31	3.15	8.65	14.8
(B)	150	.01	.02	.01	.03	.07	.05	.04	.05	.11	.23
(C)	150	.05	.08	.05	1.11	.60	.20	.15	.20	.29	.17

[a]See text for irrigation schedule.

tracted from the 150 cm depth in the wastewater irrigation fields at the three locations. At the Twin Falls site, EC in the wastewater was 2.6 to 6.8, irrigation water 0.3, soil water extracted from 150 cm depth .9 to 1.7 in summer and 5.2 mmhos/cm^2 in winter during the wastewater irrigation season. At the Rupert site EC values were as follows: wastewater 1.6 to 3.2, irrigation water 0.5, and soil water 1 to 3 mmhos/cm^2. At the Nampa site EC values were: wastewater 2.2 to 6.2, irrigation water 0.8, and soil water 1.6 to 5.1 mmhos/cm^2.

Table 7. Electrical conductivity of sugarbeet processing wastewater and of water extracted from 150 cm deep in the wastewater irrigation fields

Location (Irrigation schedule)[a]	Soil Depth cm	millimhos/centimeter^2									
		1975	1976				1977				1978
		Nov	Jan	Mar	July	Nov	Jan	Mar	July	Dec	July
Twin Falls	0	6.8	2.9	3.0	.3	2.7	4.2	3.4	.5	3.7	.5
(A)	150	4.3	4.4	3.1	3.0	3.8	3.0	4.7	2.6	2.1	-
(B)	150	1.3	3.5	3.1	2.1	3.3	3.4	3.1	-	-	.9
(C)	150	3.6	3.6	2.5	1.7	2.7	3.0	3.3	1.1	2.8	1.7
		1975	1976					1977			1978
		Nov	Jan	Apr	July	Nov	Dec	Apr	July	Dec	July
Rupert	0	2.0	2.9	.6	.5	1.0	1.4	.6	.6	1.6	.6
(A)	150	1.5	1.9	1.9	1.9	2.3	2.2	1.6	1.3	-	2.6
(B)	150	1.9	1.5	2.0	1.6	2.2	2.0	1.5	.9	3.0	2.2
(C)	150	1.3	1.5	2.2	1.8	1.5	1.9	1.4	1.1	3.0	2.6
		1976			1977					1978	
		Oct	Nov	Dec	Jan	Mar	Aug	Nov	Dec	Mar	July
Nampa	0	3.1	3.7	4.1	4.3	2.4	.8	2.1	2.1	3.9	.6
	150	.6	.7	1.2	3.4	4.7	5.1	3.4	2.4	3.0	4.0
	150	1.8	2.5	3.6	3.4	3.8	2.9	1.6	2.0	3.8	4.1

[a]See text for irrigation schedule.

Many of the EC values reported for the wastewater and for the soil water extracted from the 150 cm depth are too high for growing some crops. The irrigation water quality used during the growing season in every case was good. Salt associated with irrigation wastewater is applied in the winter when the crops living on the fields are dormant. Because the crop water requirements are low, salt concentrations in the water had little effect on the crop. Irrigating with good quality water in the spring and during the cropping season leaches the salt from the root zone and lowers the EC to acceptable levels for growing the alfalfa and grass hay.

Calcium, magnesium, and sodium concentrations were determined in the wastewater and soil water samples and are reported elsewhere (20). Sodium absorption ratios (SAR) were calculated from the calcium, magnesium, and sodium concentrations. The SAR value at all sampling sites, in all the wastewater samples, and in all soil water samples are low. Therefore no problems should exist with sodium buildup and loss of soil infiltration capacity when irrigating with these wastewaters. Wastewater SAR values at Twin Falls, Rupert, and Nampa ranged from 1.8 to 8.8, 1.0 to 3.2, and 1.6 to 4.1 respectively. SAR values in the irrigation water at the three locations were .7, .8, and 1.1 respectively. Soil water SAR values ranged from 1.6 to 3.0, 1.0 to 2.0, and 0.6 to 5.6 respectively for the three above locations. All of these values are considerably below the value that would pose a sodium hazard to the soil.

The pH values observed in the water and soil samples taken from the wastewater irrigation fields were between 6.6 and 8.4 which are within the normal range for neutral to calcareous soils. With these values, there is no reason to be concerned about the soil or water pH resulting from irrigating with these sugarbeet processing wastewaters.

COMPOSITION OF HARVESTED HAY

Chemical composition of the harvested hay samples for 1976, 1977, and 1978 are given in Table 8. These analyses include nitrate nitrogen, total nitrogen, phosphorus, and potassium. The total nitrogen analyses include nitrates and represent a fairly wide range of values from 1.63 to 3.88% total N. This corresponds to a crude protein concentration of 10.2 to 24.2% (total N x 6.25). The nitrate concentrations of the initial samplings were relatively high ranging up to 9500 ppm nitrate nitrogen. Later, the nitrate concentrations decreased to safe values for livestock feeding. Values above 2000 ppm nitrate nitrogen are considered to be hazardous to livestock. Livestock can be conditioned to high concentrations of nitrate or the feed can be diluted with other feed containing less nitrate (9). Phosphorus concentrations in the forage ranged from adequate (.2%) to high (.6%)

Table 8. Analyses of hay samples grown on sugarbeet processing wastewater irrigation fields

Location-Date	Nitrate-N	Total N	Phosphorus	Potassium
	ppm	percent		
Twin Falls				
July 1976	2250	2.22	.21	2.78
June 1977	3520	2.22	.24	3.00
Aug 1977	1090	2.98	.30	3.88
Oct 1977	2020	3.10	.25	3.14
June 1978	330	1.66	.22	3.27
July 1978	560	2.44	.20	2.72
Sept 1978	810	2.70	.29	3.04
Rupert				
July 1976	3540	2.52	.32	2.66
June 1977	1000	1.63	.28	2.99
Aug 1977	310	1.80	.23	2.76
June 1978	560	-	.28	2.71
Sept 1978	415	2.41	.21	2.08
Nampa				
Oct 1976	9500	3.08	.62	4.06
May 1977	780	3.45	.39	3.71
June 1977	220	2.32	.35	3.69
July 1977	230	2.62	.38	2.72
May 1978	70	1.65	.23	3.10
July 1978	875	3.88	.46	3.40
Sept 1978	415	3.06	.30	2.10

and should provide a phosphorus sufficient ration for livestock. Potassium concentrations in the forage were also adequate to high. With the amount of potassium being applied in the wastewater, the K content will continue to be high in the forage. Phosphorus and potassium concentrations in the forage are within satisfactory limits and should pose no problems for livestock.

SUMMARY

Wastewater irrigation rates of 10 cm per irrigation at intervals of 1, 2, or 4 weeks were established at three sugarbeet processing plants in southern Idaho having wastewater irrigation fields. The rates of irrigation used by the sugar company for disposing of wastewater on the balance of the fields was also monitored. Wastewater applications ranged from 28 to 169 cm per year with

additional high quality water used during the summer to grow hay crops on the fields. The organic matter applied in the wastewater (COD) ranged from 7.9 to 140 metric tons per ha-year or 22 to 383 kg/ha-day. These highest rates applied excessive amount of organic matter and nutrients to the fields. The range of organic matter applied to the general field areas that were not in the experimental plots was 10 to 47 metric tons/ha-year.

Nitrogen applications in the wastewater ranged from 280 to 4200 kg N/ha-yr with the range for the general field area being 277 to 1425 kg N/ha-yr. The lower nitrogen application rates could be utilized by growing plants but the highest rates were in excess of crop requirements or crop utilization capacity. Phosphorus applications were relatively low for wastewater irrigation with 5 to 50 kg P/ha-yr being applied. Phosphorus applications in many cases were lower than the crop requirements and would therefore require periodic soil tests and perhaps phosphorus fertilization. Potassium applications were in many cases very high with a range of 130 to 6350 kg K/ha-yr. Potassium applications in the wastewater will probably reach an equilibrium where the applied potassium will leach through the soil at about the same rate that it is applied.

Electrical conductivity and salts in the wastewaters are high to very high and would pose serious problems for irrigated crops if the wastewater were used during the growing season. Winter irrigation with the wastewater, when crops are dormant, increases the salt content of the soil without adversely affecting the crops. However, excess salt can be leached from the root zone of the plants with good quality irrigation water before the hay begins to grow in the spring. Even though a large amount of salt was leached through the soil in these wastewater irrigation fields, the crops grew satisfactorily and the system works well and looks good. Leaching wastewater organic constituents has been greater than would be

desired. Measurements at the 150 cm depth showed lower values of COD removal than were found with potato processing wastewater. Soil depths greater than 150 cm and the relatively short season irrigation with the wastewater should minimize organic pollution. Irrigation with good quality water in the summer has given the fields time to recover from organic loading and the soil micro-organisms decomposed the added organic residues.

The design and management of these wastewater irrigation fields has been excellent and irrigating with sugarbeet processing wastewater should continue for many years if the loading is not greater than that of the 4 week irrigation frequency.

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