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# Irrigating Agricultural Land with Sugarbeet Processing Wastewater

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*ABSTRACT*

*Some sugarbeet processors are irrigating agricultural land for the treatment and disposal of processing wastewater. The wastewater contains organic matter (COD) and inorganic nutrients, as well as inorganic salts. Experiments on irrigating with sugarbeet processing wastewater were conducted at plants in America. Wastewater irrigation schedules were imposed to determine optimum irrigation rates. Nitrogen application in the wastewater ranged from 275 to 1400* $kg\,ha^{-1}$. *Phosphorus applications were low and potassium varied widely. COD removal in some of the fields was unsatisfactory in the first year of irrigation but improved as the fields were conditioned by continued wastewater irrigation. With good management and proper loading, sugarbeet processing wastewater can be used for irrigation with satisfactory results.*

## INTRODUCTION

In recent years, irrigating agricultural land 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 (Butler *et al.*, 1974; Loehr, 1974; Meyer, 1974; Pearson *et al.*, 1972). Irrigating agricultural land for the treatment and disposal of food processing wastewater is a good practice if the wastewater does not contain toxic constituents. Crops grown on the land remove a portion of the plant nutrients supplied by the wastewater and can be fed to livestock (Adriano *et al.*, 1974; 1975).

Considerable information has been published about wastewater irrigation in recent years and several food processing wastewaters have been evaluated for irrigation use (De Haan & Zwerman, 1973; De Haan *et al.*, 1973; Smith *et al.*, 1977; Smith *et al.*, 1978). These systems work well; oxygen demand and the chemical constituents, except potassium, were satisfactorily removed at moderate application rates. Using wastewater for irrigation can economically benefit users.

Nutrient concentrations in wastewaters and feasibility for irrigation use have been evaluated for several food processing wastewaters: cannery wastes (Gilde *et al.*, 1971; Reed *et al.*, 1973), citrus wastes (Koo, 1974), vegetable wastes (Soderquist & Graham, 1972; Soderquist *et al.*, 1972; Pearson, 1975; Timm *et al.*, 1976), fruit processing wastes (Soderquist & Graham, 1972; Soderquist *et al.*, 1972; White, 1973; Rauschkolb *et al.*, 1975) and grain wastes (Soderquist & Graham, 1972). For the most part these wastewaters can be used for irrigating agricultural land with a minimum of problems.

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 may be applied to fields.

The objectives of this paper are to (a) summarize data for flood irrigation with sugarbeet processing wastewater, (b) evaluate soil loading with nutrients and organic matter, (c) examine water cleanup through soil filtration and microbiological activity, (d) observe some aspects of nutrient utilization, (e) consider salinity and specific ions in the soil and (f) discuss the feasibility of continued irrigation with sugarbeet processing wastewater.

## METHODS

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 fields were designed and prepared for irrigation by grading to rigid specifications for surface irrigation and diking the fields to prevent runoff. The fields, seeded with an orchard grass (*Dactylis glomerata*) and alfalfa (*Medicago sativa*) mixture, were harvested for hay during the summer growing season. Wastewater was sampled at each 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. It was frozen in a plastic container and stored until analyzed (Fisher & Smith, 1975). 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 polyvinyl-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 70 kPa (0·7 bar) suction was applied to the tubes for about 48 h. 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 (American Public Health Association, 1971). 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 (American Public Health Association, 1971). Total phosphorus was determined by persulfate oxidation (USEPA, 1974) and potassium by flame photometry. Water applications to the fields were measured by the field operators using water meters. Processing plant 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 Fall 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 & Hayden (1980).

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

## RESULTS AND DISCUSSION

### Wastewater irrigation

Wastewater applications at the fields were at planned rates of 10 cm per irrigation and initially scheduled at 1-week (A), 2-week (B) or 4-week (C) intervals. Irrigations applied by the treatment field operators to dispose of the wastewater were designated (D). After the first irrigation season, it was decided that the weekly irrigation schedule was excessive and therefore this treatment was terminated and the plots were then irrigated according to schedule (D). The irrigations at the different sites are shown in Table 1. For a complete listing of all wastewater irrigations see Smith & Hayden (1980). The COD, nitrogen, phosphorus and potassium applications in the wastewater application are shown in Table 1. The weekly applications applied excessive amounts of COD, nitrogen and potassium. The 140 metric tons of COD applied in the first year at the Twin Falls site and the 61 tons supplied at Rupert both damaged the vegetation because of the development of anaerobic conditions associated with the high water and organic additions. 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. 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 phosphorus to maintain optimum fertility for growing hay crops.

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

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* ($tons\,ha^{-1}$) | *Nitrogen* ($kg\,ha^{-1}$) | *Phosphorus* ($kg\,ha^{-1}$) | *Potassium* ($kg\,ha^{-1}$) |
|---|---|---|---|---|---|
| Twin Falls | | | | | |
| (A) Weekly† | 155 | 139·5 | 4 200 | 34 | 2 820 |
| (B) 2 weeks | 87 | 46·6 | 1 582 | 13 | 1 005 |
| (C) 4 weeks | 48 | 22·3 | 860 | 7 | 630 |
| (D) 1976–77‡ | 42 | 17·1 | 555 | 14 | 1 095 |
| (D) 1977–78 | 169 | 46·9 | 1 425 | 13 | 3 405 |
| Rupert | | | | | |
| (A) Weekly | 109 | 60·6 | 1 150 | 16 | 430 |
| (B) 2 weeks | 48 | 28·0 | 570 | 8 | 195 |
| (C) 4 weeks | 28 | 15·1 | 335 | 5 | 130 |
| (D) 1976–77 | 50 | 10·0 | 335 | 11 | 510 |
| (D) 1977–78 | 28 | 8·1 | 370 | 13 | 490 |
| Nampa | | | | | |
| (D) 1976–77 | 116 | 10·4 | 277 | 15 | 3 080 |
| (D) 1977–78 | 114 | 9·7 | 383 | 16 | 3 410 |

* See text for irrigation schedules.
† 1975–1976 processing season.
‡ Represents average applications to entire field during processing season.

location. 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 8000 mg liter$^{-1}$. 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 2000 to 8200 mg liter$^{-1}$ and the average in the Twin Falls wastewater for the second and third processing seasons was approximately 3300 mg liter$^{-1}$. At the Rupert field, COD ranged from 1500 to 5300 and averaged 3300 mg liter$^{-1}$ for the three processing seasons. COD concentrations at the Nampa plant ranged from 345 to 2000 and averaged 1100 mg liter$^{-1}$ 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 fields, an average of 48 % reduction was found for the three processing seasons during the 4-week irrigation schedule. At the Rupert fields, the wastewater COD averaged 3450 and the soil water COD averaged 550 mg liter$^{-1}$ (an 84 % average reduction) for 3 years. At the Nampa fields the wastewater COD averaged 1050 and the soil water, 268 mg liter$^{-1}$ (a 75 % average 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 fields, the soil was deeper than 150 cm and the organic material cleanup by filtration and biological activity would continue as the water infiltrated deeper into the soil profile. This should ultimately produce a clean effluent. High total nitrogen (Table 3) was found in the early wastewater samples from the Twin Falls plant, and this corresponded with high COD concentrations. The average total N for the first season was 210 and for three seasons was 132 mg liter$^{-1}$. The average total N remaining in the water extracted from the 150 cm depth was 4 mg liter$^{-1}$ (a 97 % decrease). Average total N for three seasons at Rupert was 75 mg liter$^{-1}$ and average soil water N was 2·4 mg liter$^{-1}$ at the 150 cm depth (a 98 % decrease). The average total N in the wastewater at Nampa was 36 mg liter$^{-1}$ and average soil water N was 4 mg N per liter (an 88 % decrease).

Nitrate-N in the wastewater was low, with $<1$ mg liter$^{-1}$ at the three locations (Table 4). 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$^{-1}$, but if three high nitrate values are removed from the total before averaging the concentrations, the mean of the remaining values is 8·7 mg $NO_3$-N liter$^{-1}$. Many samples had $NO_3$-N concentrations below 1 mg liter$^{-1}$. 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 liter$^{-1}$. Concentrations at

Nampa were intermediate with a range of 0 to 30 and an average of 7·8 mg $liter^{-1}$.

Phosphorus concentrations in the wastewater were low, which resulted in relatively small applications of phosphorus (Table 5). The normal irrigation rates for the three fields would not maintain the fields at adequate phosphorus levels. Phosphorus in the wastewater at Twin Falls averaged 1·9 and ranged from 0·8 to 4·1 mg $liter^{-1}$. At Rupert the average was 1·8 and ranged from 0·7 to 4·3 mg $liter^{-1}$. At Nampa the average was 1·7 and ranged from 0·3 to 2·9 mg $liter^{-1}$. The average concentrations at the 150 cm soil depth were 0·19, 0·12, and 0·62 mg $liter^{-1}$ for the Twin Falls, Rupert and Nampa sites, respectively. These low concentrations should minimize P leaching through the soil. The higher P concentration in the soil water at the Nampa site compared with the other two sites was 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 (Table 6). Potassium concentration in the wastewater at Twin Falls averaged 5·6 and ranged from 1·1 to 13·2 meq K per liter. At Rupert the average was 3·2 and ranged from 1·6 to 7·3 meq K per liter. At Nampa the average was 7·3 and ranged from 3·2 to 14·8 meq K per liter. Potassium concentrations in the soil water extracted from the 150 cm depth were 2·3, 0·21, and 0·21 meq K per liter for Twin Falls, Rupert and Nampa, respectively.

A large amount of K was being applied to these fields and varying amounts are leached 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), a reflection of the 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 extracted from the 150 cm depth in the fields. 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, 0·9 to 1·7 mmhos $cm^{-2}$ in summer and 5·2 mmhos $cm^{-2}$ in winter during the wastewater irrigation season. At the Rupert site EC values were: 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 2**
Chemical Oxygen Demand (COD) in Sugarbeet Processing Wastewater and in Water Extracted from 150 cm Depth in the Wastewater Irrigation Fields

| *Location (Irrigation schedule)** | *Soil Depth (cm)* | *Milligrams per liter* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *1975* | | *1976* | | | | | | |
| | | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Mar.* | *Apr.* | *May* | *June* | *July* |
| Twin Falls | 0 | 20 | 8 215 | 5 795 | 5 200 | 5 970 | 3 275 | 2 920 | 20 | 20 | 20 |
| (A) | 150 | 55 | 2 040 | 4 825 | 4 200 | 4 030 | 2 795 | 1 655 | 1 380 | 1 560 | 1 375 |
| (B) | 150 | 30 | 45 | 3 865 | 3 580 | — | 2 840 | 1 710 | — | 1 145 | 1 050 |
| (C) | 150 | 75 | 2 005 | 4 620 | 3 710 | — | 1 945 | 1 695 | — | 495 | 70 |
| | | *1976* | | *1977* | | | | | | *1978* | |
| | | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Mar.* | *July* | *Nov.* | *Dec.* | *Apr.* | *July* |
| | 0 | 2 955 | 4 850 | 3 830 | 3 600 | 1 995 | 20 | 3 070 | 2 915 | 20 | 20 |
| (A) | 150 | 1 090 | 585 | 230 | 305 | 1 030 | 130 | — | 605 | 610 | 185 |
| (B) | 150 | 580 | 2 195 | 2 605 | 1 975 | 1 590 | 125 | 1 160 | — | 400 | 85 |
| (C) | 150 | 2 150 | 3 565 | 2 520 | 1 730 | 1 540 | 80 | 1 525 | 1 430 | 360 | 115 |

| | | 1975 | | | 1976 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Apr.* | *Aug.* | *Oct.* | *Nov.* | *Dec.* |
| **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 |
| | | 1977 | | | | | | 1978 | | | |
| | | *Jan.* | *Apr.* | *July* | *Sept.* | *Oct.* | *Dec.* | *May* | *July* | | |
| | 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 | | |
| | | 1976 | | | 1977 | | | | | | |
| | | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Mar.* | *July* | *Nov.* | *Dec.* | *Mar.* | *May* |
| 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 |

* See text for irrigation schedules.

—, Not determined.

**TABLE 3**
Total Nitrogen in Sugarbeet Processing Wastewater and in Water Extracted from 150 cm Depth in Wastewater Irrigation Fields

| *Location (Irrigation schedule)** | *Soil depth (cm)* | *Milligrams per liter* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Oct.* | *1975 Nov.* | *Dec.* | *1976 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 |
| | | *Dec.* | *1977 Jan.* | *Feb.* | *Mar.* | *June* | *July* | *Sept.* | *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 | Sept. | 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 |

* See text for irrigation schedules.
—, Not determined.

**TABLE 4**

Nitrate-Nitrogen in Sugarbeet Processing Wastewater and in Water Extracted from 150 cm Depth in Wastewater Irrigation Fields

| *Location (Irrigation schedule)** | *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 |

* See text for irrigation schedule.
—, Not determined.

**TABLE 5**

Total Phosphorus in Sugarbeet Processing Wastewater and in Water Extracted from 150 cm Depth in the Wastewater Irrigation Fields

| *Location (Irrigation schedule)** | *Soil depth (cm)* | *Milligrams per liter* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *1975* | | *1976* | | | | | | |
| | | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Mar.* | *Apr.* | *May* | *June* | *July* |
| Twin Falls | 0 | — | 0·85 | 1·23 | 1·21 | 2·08 | 2·00 | 1·10 | 0·23 | 0·05 | 0·18 |
| (A) | 150 | 0·09 | 0·05 | 0·10 | 0·08 | 0·07 | 0·16 | 0·55 | 0·57 | 0·43 | 0·26 |
| (B) | 150 | 0·05 | 0·08 | 0·10 | 0·05 | — | 0·15 | 0·07 | — | 0·15 | 0·25 |
| (C) | 150 | 0·06 | 0·07 | 0·04 | 0·05 | — | 0·16 | 0·08 | — | 0·09 | 0·16 |
| | | | | *1977* | | | | | | *1978* | |
| | | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Mar.* | *July* | *Nov.* | *Dec.* | *Apr.* | *July* |
| | 0 | 2·08 | 3·84 | 4·06 | — | 1·02 | 0·16 | 2·31 | 3·10 | 0·79 | 0·26 |
| (A) | 150 | 0·22 | 0·12 | 0·06 | — | — | 0·56 | 0·14 | 0·16 | — | 0·22 |
| (B) | 150 | 0·08 | 0·16 | 0·08 | — | — | — | 0·13 | — | — | — |
| (C) | 150 | 0·06 | 0·06 | 0·12 | 0·08 | 0·08 | 0·11 | 0·12 | 0·14 | — | 0·06 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *1975* | | | *1976* | | | | | | |
| | | *Oct.* | *Nov.* | *Dec.* | *Jan.* | *Feb.* | *Apr.* | *Aug.* | *Oct.* | *Nov.* | *Dec.* |
| Rupert | 0 | 1·23 | 1·37 | 2·08 | 1·90 | 0·68 | 0·47 | 0·10 | 1·71 | 1·67 | 2·61 |
| (A) | 150 | 0·07 | 0·02 | 0·02 | 0·04 | 0·07 | 0·16 | 0·50 | 0·08 | 0·25 | 0·38 |
| (B) | 150 | 0·27 | 0·10 | 0·08 | 0·06 | — | 0·19 | 0·11 | 0·07 | 0·14 | 0·11 |
| (C) | 150 | 0·04 | 0·01 | 0·03 | 0·02 | — | 0·12 | 0·10 | 0·05 | 0·04 | 0·48 |
| | | *1977* | | | | | | *1978* | | | |
| | | *Jan.* | *Apr.* | *July* | *Sept.* | *Oct.* | *Dec.* | *May* | *July* | | |
| | 0 | 4·27 | 0·02 | 0·12 | 0·75 | 2·59 | 2·28 | 0·05 | 0·10 | | |
| (A) | 150 | — | 0·06 | 0·06 | 0·06 | — | — | 0·20 | 0·08 | | |
| (B) | 150 | — | 0·12 | 0·06 | 0·04 | 0·06 | 0·12 | 0·09 | 0·26 | | |
| (C) | 150 | 0·04 | 0·04 | 0·12 | 0·09 | 0·06 | 0·08 | 0·08 | 0·11 | | |
| | | *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 | 0·24 | 0·31 | 0·44 | 0·26 | 0·17 | 0·20 | 0·15 | 0·13 | 0·19 | 0·12 |
| (C) | 150 | 1·29 | 1·16 | 1·24 | 0·96 | 0·37 | 1·03 | 1·04 | 0·90 | 0·63 | 0·81 |

* See text for irrigation schedule.
—, Not determined.

**TABLE 6**

Potassium in Sugarbeet Processing Wastewater and in Water Extracted from 150 cm Depth in the Wastewater Irrigation Fields

| *Location (Irrigation schedule)** | *Soil depth (cm)* | *Milliequivalents per liter* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *1975 Nov.* | *Dec.* | *1976 Jan.* | *Feb.* | *Mar.* | *Apr.* | *May* | *June* | *July* | *Nov.* |
| Twin Falls | 0 | 13·2 | 7·5 | 5·9 | 6·4 | 4·9 | 3·3 | 0·02 | 0·1 | 0·1 | 5·4 |
| (A) | 150 | 2·1 | 6·8 | 4·2 | 4·6 | 6·0 | 3·3 | 0·2 | 0·4 | 0·3 | 1·6 |
| (B) | 150 | 0·1 | 4·8 | 2·9 | — | 4·8 | 3·9 | — | 0·1 | 0·2 | 2·6 |
| (C) | 150 | 1·4 | 4·7 | 3·0 | — | 4·2 | 3·4 | — | 0·1 | 0·1 | 0·9 |
| | | *Dec.* | *1977 Jan.* | *Feb.* | *Mar.* | *May* | *July* | *Nov.* | *Dec.* | *1978 Apr.* | *July* |
| | 0 | 7·2 | 6·1 | 5·5 | 2·9 | 0·1 | 0·7 | 5·4 | 5·7 | 3·0 | 0·1 |
| (A) | 150 | 3·8 | 1·7 | — | 3·5 | 0·1 | 0·4 | 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 | 0·18 | 0·18 | 1·61 | 1·75 | 3·23 |
| (A) | 150 | 0·13 | 0·13 | 0·11 | 0·06 | 0·09 | 0·10 | 0·17 | 0·14 | 0·14 | 0·07 |
| (B) | 150 | 0·16 | 0·15 | 0·28 | 0·11 | — | 0·08 | 0·18 | 0·16 | 0·18 | 0·09 |
| (C) | 150 | 0·06 | 0·10 | 0·10 | 0·11 | — | 0·06 | 0·17 | 0·13 | 0·11 | 0·02 |
| | | *1977* | | | | | | *1978* | | | |
| | | *Jan.* | *Apr.* | *July* | *Sept.* | *Oct.* | *Dec.* | *May* | *July* | *Aug.* | |
| | 0 | 3·83 | 0·15 | 0·13 | 3·78 | 2·39 | 1·84 | 0·89 | 0·16 | 0·14 | |
| (A) | 150 | — | 0·10 | 0·14 | 0·17 | — | — | 0·51 | 0·62 | 0·94 | |
| (B) | 150 | — | 0·16 | 0·24 | 0·18 | 0·32 | 0·62 | 0·74 | 0·57 | 0·56 | |
| (C) | 150 | 0·10 | 0·08 | 0·07 | 0·11 | 0·16 | 0·24 | 0·30 | 0·23 | 0·24 | |
| | | *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 | 0·01 | 0·02 | 0·01 | 0·03 | 0·07 | 0·05 | 0·04 | 0·05 | 0·11 | 0·23 |
| (C) | 150 | 0·05 | 0·08 | 0·05 | 1·11 | 0·60 | 0·20 | 0·15 | 0·20 | 0·29 | 0·17 |

* See text for irrigation schedule.
—, Not determined.

**TABLE 7**
Electrical Conductivity of Sugarbeet Processing Wastewater and of Water Extracted from 150 cm Depth in the Wastewater Irrigation Fields

| Location (Irrigation schedule)* | Soil depth (cm) | Millimhos $cm^{-2}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *1975 Nov.* | *1976 Jan.* | *Mar.* | *July* | *Nov.* | *1977 Jan.* | *Mar.* | *July* | *Dec.* | *1978 July* |
| Twin Falls | 0 | 6·8 | 2·9 | 3·0 | 0·3 | 2·7 | 4·2 | 3·4 | 0·5 | 3·7 | 0·5 |
| (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 | — | — | 0·9 |
| (C) | 150 | 3·6 | 3·6 | 2·5 | 1·7 | 2·7 | 3·0 | 3·3 | 1·1 | 2·8 | 1·7 |
| | | *1975 Nov.* | *1976 Jan.* | *Apr.* | *July* | *Nov.* | *Dec.* | *1977 Apr.* | *July* | *Dec.* | *1978 July* |
| Rupert | 0 | 2·0 | 2·9 | 0·6 | 0·5 | 1·0 | 1·4 | 0·6 | 0·6 | 1·6 | 0·6 |
| (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 | 0·9 | 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 Oct.* | *Nov.* | *Dec.* | *1977 Jan.* | *Mar.* | *Aug.* | *Nov.* | *Dec.* | *1978 Mar.* | *July* |
| Nampa | 0 | 3·1 | 3·7 | 4·1 | 4·3 | 2·4 | 0·8 | 2·1 | 2·1 | 3·9 | 0·6 |
| (B) | 150 | 0·6 | 0·7 | 1·2 | 3·4 | 4·7 | 5·1 | 3·4 | 2·4 | 3·0 | 4·0 |
| (C) | 150 | 1·8 | 2·5 | 3·6 | 3·4 | 3·8 | 2·9 | 1·6 | 2·0 | 3·8 | 4·1 |

* See text for irrigation schedule.
—, Not determined.

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 quality of the irrigation water used during the growing season in every case was good. Salt associated with irrigation wastewater is applied in the winter when the crops on the fields are dormant. Because the water requirements of the crops are then low, salt concentrations in the water have 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 alfalfa and grass.

Calcium, magnesium and sodium concentrations were determined in the wastewater and soil water samples and are reported elsewhere (Smith & Hayden, 1980). Sodium absorption ratios (SAR) were calculated from the calcium, magnesium and sodium concentrations. The SAR values at all sampling sites, in all the wastewater samples, and in all soil water samples were 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 0·7, 0·8 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. 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—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.

## Harvested hay

Chemical compositions of the harvested hay samples for 1976, 1977 and 1978 are given in Table 8. 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 × 6·25). The nitrate concentrations of the initial samplings were relatively high, up to 9500 ppm. Later, the concentrations decreased to safe values for livestock feeding. Values above 2000 ppm nitrate-nitrogen are considered to be hazardous to livestock. However, livestock can be conditioned to high concentrations of nitrate or the feed can be diluted with other feed containing less nitrate (Hill *et al.*, 1972). Phosphorus

**TABLE 8**
Analyses of Hay Samples Grown on Sugarbeet Processing Wastewater Irrigation Fields

| *Location–date* | *Nitrate-N* (*ppm*) | *Total N* (%) | *Phosphorus* (%) | *Potassium* (%) |
|---|---|---|---|---|
| Twin Falls | | | | |
| July, 1976 | 2 250 | 2·22 | 0·21 | 2·78 |
| June, 1977 | 3 520 | 2·22 | 0·24 | 3·00 |
| Aug., 1977 | 1 090 | 2·98 | 0·30 | 3·88 |
| Oct., 1977 | 2 020 | 3·10 | 0·25 | 3·14 |
| June, 1978 | 330 | 1·66 | 0·22 | 3·27 |
| July, 1978 | 560 | 2·44 | 0·20 | 2·72 |
| Sept., 1978 | 810 | 2·70 | 0·29 | 3·04 |
| Rupert | | | | |
| July, 1976 | 3 540 | 2·52 | 0·32 | 2·66 |
| June, 1977 | 1 000 | 1·63 | 0·28 | 2·99 |
| Aug., 1977 | 310 | 1·80 | 0·23 | 2·76 |
| June, 1978 | 560 | — | 0·28 | 2·71 |
| Sept., 1978 | 415 | 2·41 | 0·21 | 2·08 |
| Nampa | | | | |
| Oct., 1976 | 9 500 | 3·08 | 0·62 | 4·06 |
| May, 1977 | 780 | 3·45 | 0·39 | 3·71 |
| June, 1977 | 220 | 2·32 | 0·35 | 3·69 |
| July, 1977 | 230 | 2·62 | 0·38 | 2·72 |
| May, 1978 | 70 | 1·65 | 0·23 | 3·10 |
| July, 1978 | 875 | 3·88 | 0·46 | 3·40 |
| Sept., 1978 | 415 | 3·06 | 0·30 | 2·10 |

—, Not determined.

concentrations in the forage ranged from adequate (0·22 %) to high (0·6 %) 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.

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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