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Treatment of Potato Processing Waste Water on Agricultural Land[1]

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ABSTRACT

The chemical oxygen demand (COD) and the total N and NO_3^--N concentrations in potato (*Solanum tuberosum* L.) processing plant waste water and in the soil solution at several depths in a treatment field where the waste water was applied were studied for a 2-year period. The COD decreased 95 to 99% from 850 to 2,000 ppm in waste water to 4 to 40 ppm after passing through 150 cm of soil. A similar decrease in the total N concentration was found. The NO_3^--N concentration in the waste water ranged from 0.1 to 9.0 ppm and the concentration in the soil solution at the 150-cm depth was generally $<$1.0 ppm. During the second year 1,076 kg N/ha were applied in the waste water. The grass crop removed about 320 kg N/ha (about 30% of that applied). Results indicated that only about 10 kg N/ha passed into the water table each year. Land disposal is a practical method for disposing of potato processing waste waters with a low pollution potential.

Additional Index Words: COD, nitrate, total nitrogen, soil water, irrigation, organic matter decomposition.

Food processing industries discharge large volumes of waste water that are generally characterized by high chemical oxygen demand (COD), large amounts of suspended solids, and various inorganic constituents including N and P (8, 9, 10). Application of these waste waters to agricultural land may (i) promote growth of crops, (ii) conserve water and nutrients otherwise wasted, (iii) provide economical treatment of the waste water, and (iv) decrease the pollution load on surface water supplies (11). Wilcox (12) summarized the effects of a variety of industrial pollutants and recommended treatment systems for using these effluents for agricultural irrigation. He indicated that industrial waste waters containing high concentrations of inorganic and organic constituents, such as paper pulp, potato, and other food processing effluents, generally are well suited for land disposal.

Since it was first tried in 1947, sprinkler irrigation with cannery and food processing wastes has greatly increased in the U. S. (2, 3, 4). Drake and Bier (5) presented operating data from several pea (*Pisum sativum* L.) and corn (*Zea mays* L.) canneries in Minnesota showing the economic as well as physical limitations of using the land disposal method. They reported that the following problems may develop: (i) organic matter may accumulate on plants and provide a suitable environment for fungi and other harmful growths, (ii) prolonged irrigation of a particular field may deteriorate the soil structure, (iii) roots of plants may rot if soaked too often, and (iv) diseases may spread from processed products to crops being irrigated. Luley (7) discussed limitations of terrain for sprinkler irrigation with waste waters from three eastern canneries. He classified the systems as practical, simple in concept, straightforward in operation, and generally adaptable to the various soil conditions and terrain with careful planning and control. While sprinkler irrigation is emphasized, gravity flow irrigation where applicable will serve equally well, and in cold weather will decrease ice buildup problems and allow water infiltration when the soil and water would freeze if applied with sprinklers.

Systems can be designed for using most waste water for irrigation. However, much remains to be learned about the soil chemical and physical changes resulting from application of waste waters. Such applications may produce beneficial or deleterious changes in the soil system. The research reported here was designed to evaluate the system in operation; to determine COD, NO_3^--N, and total N in the waste water, and to determine changes in soil solution composition as waste effluents passed through the soil.

METHODS AND MATERIALS

The study was conducted at a potato processing plant in Idaho where the waste water was applied by gravity flow to bordered areas of Heiston soil. The processor peeled the potatoes (*Solanum tuberosum* L.) with steam, therefore, sodium was not a problem. Water was applied to the treatment fields throughout two processing seasons, including winters, except when the plant was closed for a few days in early Dec. 1972 when the air temperature dropped below minus 40C. The low temperature made it impractical to truck potatoes from storage to the processing plant because they would freeze en route. No serious infiltration problems were encountered when effluent applications to the field were resumed, because the warm effluent water thawed the frozen soil solution at each application.

Water applications were measured using a water meter in the pipeline that carried the waste water from the processing plant to the field. Twenty-four hour composited samples of the waste water were collected automatically in a freezer and kept frozen until they were thawed for analyses (6). Soil water was sampled monthly through sampling tubes constructed from 3.8-cm diameter polyvinylchloride pipe with porous ceramic cups cemented to one end. The sampling tubes were inserted into the soil in vertically

Table 1—Soil mechanical analyses of waste water treatment fields*

Sampling depth	Clay	Sand	Silt	Textural class
cm		%		
		Site 1		
0-30	12	66	22	Sandy loam
30-61	17	49	34	Loam
61-91	14	57	29	Loamy sand/sandy loam
91-122	17	53	30	Sandy loam
122-152	16	51	33	Loam/sandy loam
152-178	26	24	50	Silt loam/loam
		Site 2		
0-30	18	38	44	Loam
30-61	13	64	23	Sandy loam
61-91	23	26	51	Silt loam
91-122	19	32	49	Silt loam/loam
122-152	21	25	54	Silt loam
152-244	9	76	15	Sandy loam

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drilled holes 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, and water in the soil held at a lower tension was extracted. Not every tube yielded a water sample at every sampling. Usually the vacuum was allowed to remain on the tubes for 48 hours, after which the water was pumped into a suction flask, transferred to a plastic bottle, and taken to the laboratory for refrigerated storage until analyzed. A mixture of reed canary grass (*Phalaris arundinacea*) and tall fescue (*Festuca arundinacea*) grown on the fields was sampled at each harvest for chemical analyses. Yield was estimated from harvest data supplied by the operator for use in calculating nutrient recovery.

The water samples were analyzed for COD according to standard methods for the examination of water and waste water (1). Nitrate-N was determined with a nitrate-specific ion electrode. Total N was determined by a Kjeldahl procedure, modified by substituting copper for the mercury catalyst (1). Particle-size analyses of the soils were obtained from each sampling depth for determining texture (Table 1).

RESULTS AND DISCUSSION

Potato processing began in Oct. and continued into the following June or July. For two full processing seasons covering 21 months of sampling and ending in July 1974, the COD in the potato processing effluent water ranged from 850 to 2,035 ppm (Table 2). Company records of water applied to the land showed that applications ranged from 6 to 40 cm/month with total water applications of 266 cm for the 1972-73 and 201 cm for the 1973-74 seasons. COD application for the same time ranged from 785 to 6,390 kg/ha per month, with a total of 40,900 kg/ha for the first and 29,300 kg/ha for the second year. COD applications to the waste treatment field for 305-day processing seasons averaged 134 kg/ha day the first and 96 kg/ha day the second year. Nitrogen applications ranged from 25 to 275 kg/ha per month with total applications of 1,635 kg N/ha the first and 1,080 kg N/ha the second year (Table 2).

Soil water samples were obtained from most of the samplers during 21-months of samplings covering two processing seasons. Sometimes insufficient soil water was obtained for all the analyses desired. However, sufficient water was obtained for COD determinations in 165 of the possible 240 soil solution samples. The COD decreased sharply as the waste water passed through the soil (Table 3). Table 3 shows results from quarterly samplings; results from the other samplings were similar. COD decreased 80 to 97% from the effluent COD in the top 15 cm of soil, increased sometimes in the 30- to 60-cm samples, and decreased further at greater soil depths. There is some evidence that the COD concentrations in the soil water samples at 60 cm and deeper are normal background concentrations. Therefore COD cleanup may have been 100%.

Table 2—Waste water, COD, and nitrogen applied in waste water to a water treatment field (1972-74)

	Water applied		COD				Nitrogen	
Month	72-73	73-74	72-73	73-74	72-73	73-74	72-73	73-74
	cm		mg/liter		kg/ha		kg/ha	
Oct.	29	13	1,545	1,320	4,485	1,670	195	65
Nov.	10	21	1,610	1,200	6,390	3,715	275	125
Dec.	26	32	1,660	1,485	4,370	4,675	185	165
Jan	36	32	1,310	1,575	4,710	5,080	195	195
Feb.	24	19	2,035	1,220	4,930	2,595	190	130
Mar.	18	18	1,600	1,665	2,800	2,945	105	100
Apr.	32	21	1,765	1,600	5,720	3,345	215	140
May	26	23	1,075	1,410	2,800	4,255	110	130
June	29	12	1,345	850	3,925	1,000	140	30
July	6		890		785	--	25	--
Total	266	201	--	-	40,915	29,280	1,635	1,080

Table 3—Chemical oxygen demand (COD) of potato processing effluent and of water samples extracted from the waste treatment field at various depths

	COD						
	1973				1974		
Soil depth	31 Jan.	27 Apr.	3 Aug.	2 Nov.	15 Feb.	3 May	15 Aug.
cm	ppm						
0*	1,310	1,765	890	1,200	1,221	1,408	--
				Site 1			
15	47	67	36	--	33	24	–
30	43	46	30	47	--	--	–
60	--	42.	43	50	52	25	–
90	--	--	75	52	56	33	48
120	--	--	66	--	–	70	61
150	--	40	22	31	52	30	38
				Site 2			
15	43	38	17	25	34	11	--
30	585	38	8	30	--	0	21
60	43	594	66	--	--	11	23
90	25	31	20	20	36	7	--
120	21	17	9	22	22	7	25
150	--	12	11	13	32	4	17

* Plant effluent water was collected in the pump house at the waste treatment field. All waste water was passed through a primary clarifier and the solids removed by continuous vacuum filtration.

Only 103 of the 240 soil solution samples contained the 100 ml of water required for total N analysis. Those data points presented in Table 4 show a decrease in total N in the soil water samples similar to the decrease in COD. Although the total N in the effluent water from potato processing ranged from 40 to 67 ppm, the water samples obtained from the 150-cm depth ranged from 0 to 1.7 ppm. This showed that almost none of the N-containing organic materials in the water passed through the soil. However, the large amount of N added to the soil in the waste water could become a ground-water pollutant. Organic matter decomposition and the associated N mineralization will ultimately release most of the organic N. To avoid pollution of the ground water, the N mineralized from the potato wastes must be utilized by growing plants, retained in the soil, or denitrified.

The NO_3^- values presented in Table 5 show that one water sample taken from the top 30 cm of soil contained 8.6 ppm NO_3^--N. At some sampling dates, nitrate concentrations decreased with soil depth and at the 150-cm depth, the maximum NO_3^- found was 2.3 ppm N. On other sampling dates, NO_3^- was low throughout the soil profile. Some of the added organic matter probably remained undecomposed and with time decomposition would release more N. Denitrification seems to be a logical explanation for the low NO_3^- values found with increasing soil depth. The low NO_3^--N values reported in this study indicate that with the system used in this one potato processing waste treatment field, NO_3^--N may present little ground-water pollution hazard.

Although water application was excessive for high irrigation efficiency, generally the crop was not damaged except by ponding in small areas during the winter. Soil

Table 4—Total nitrogen in potato processing effluent water and water samples extracted from waste water treatment field

	Nitrogen						
	1973				1974		
Soil depth	21 Jan.	27 Apr.	2 Aug.	2 Nov.	15 Feb.	3 May	15 Aug.
cm	ppm						
0*	54	67	--	40	60	21	--
			Site 1				
15	--	3.5	--	--	--	--	--
30	--	0.0	0.8	--	--	--	--
60	--	0.3	0.3	--	--	--	--
90	--	--	--	3.8	--	--	--
120	--	--	--	--	--	--	--
150	0.0	0.4	0.9	0.0	1.7	0.9	1.3
			Site 2				
15	1.1	1.5	1.4	3.5	--	--	--
30	1.0	0.9	1.1	2.6	–	0.8	--
60	0.5	1.2	--	--	–	1.0	1.1
90	--	2.7	1.5	2.3	--	0.5	--
120	0.5	0.3	1.2	1.7	1.2	0.2	0.2
150	–	--	0.2	0.3	1.2	1.0	0.4

* See Table 3.

infiltration remained adequate throughout the season. Estimates of evaporation for the 6 months from Oct. through Mar. were 15 cm of water. With 173 cm of waste water applied from Oct. through Mar., an excess of 158 cm of water was applied, which infiltrated the soil and entered the ground water. During Apr. through July, 91 cm of water were applied and 61 cm transpired, for a 30 cm excess. The following 2 months while the potato processing plant was not operating, the fields were irrigated from the canal to meet water requirements of the grass. During the 1972-73 processing season, approximately 190 cm of waste water in excess of evapotranspiration were applied to the treatment field. During the 1973-74 potato processing season less processing water was applied than in the previous season. Assuming evapotranspiration losses to be similar to the previous year, the excess waste water applied to the treatment field during the 1973-74 processing season was approximately 125 cm that entered the ground water. Precipitation from Oct. to Dec. 1972 was 6 cm, 1973 was 31 cm, and Jan. to July 1974 was 12 cm at the weather station at the Idaho Falls airport. It was probably similar at the waste treatment field.

Two crops of hay were harvested from the treatment fields during the summer of 1973. The first crop yielded 2.86 metric tons hay/ha and averaged 3.0% N. The second crop yielded 4.08 metric tons hay/ha containing 2.4% N. The total N harvested with the hay crops was 184 kg/ha. In 1974 the hay yield was much greater than 1973 and the first crop harvested yielded 6.73 metric tons/ha of good quality hay containing 2.37% N. The second crop of hay was grazed off with beef cows and calves so no yield measurements were obtained. When the hay was harvested mechanically, the field was dried out for a longer time and regrowth was slower than when it was grazed. If both crops had been harvested, the yields and N recovered should have been similar. Nitrogen harvested in 1974 was approximately 160 kg/ha in the first cutting, therefore I assume approximately 320 kg N/ha were harvested for the year. With 1,076 kg N applied in the waste water, the harvested nitrogen represents about 30% of the applied nitrogen and becomes an important factor in management of the treatment field.

Calculations of a N balance in the system would be desirable, but two factors make it impossible. The N applied to the field in the potato processing waste water was primarily in the organic form. Decomposition of the organic matter and mineralization of the N are necessary for crop utilization or major movement of the N, and the amount of decomposition is unknown. Soil samples have been taken and will be analyzed for organic matter content and N. The precision of measuring increasing organic content in the presence of existing soil organic matter is very poor. Therefore, a measurement of soil organic matter is not likely to provide much information on N balance. The N measurements may be somewhat better. Denitrification probably removed considerable N from the system. Because of energy rich materials present, the water table ranging from 90 to 150 cm below the soil surface in the summer, and excessive irrigation, much of the added N is probably being denitrified. The soil redox potential measurements appeared to support the denitrification hypothesis.

Nitrate concentrations in the soil water at the 152-cm depth were low during the 1972-73 processing season. Therefore, leaching will account for only a small part of the added N. Excess water applied to the treatment field was about 19 million kg/ha the first and 11 million kg/ha the second processing season. Based on the NO_3^- concentrations in the waste water at the 150-cm soil depth, < 10 kg N/ha was leached each year.

The leaching losses postulated here are based upon the assumption that the NO_3^- concentrations in the soil water samples were representative. Possibly, concentrations of NO_3^- were higher in the wetting front water at each irrigation than at the regular samplings. If wetting front NO_3^- concentrations were higher than NO_3^- observed in the regular water samples, NO_3^- leaching losses may have been greater than estimated. Many soil water samples were obtained, some of which likely came from the wetting front. Another expected result of elevated wetting front NO_3^- concentrations would be higher than normal

Table 5—Nitrate-N in potato processing effluent water and water samples extracted from the waste water treatment field

	Nitrate-N						
	1973				1974		
Soil depth	31 Jan.	27 Apr.	3 Aug.	5 Oct.	11 Jan.	3 May	15 Aug.
cm	ppm						
0*	0.5	9.0	--	0.1	0.2	2.6	--
			Site 1				
15	--	0.5	0.7	--	--	2.0	--
30	0.3	0.4	0.0	0.0	0.8	--	--
60	--	0.0	0.0	--	--	2.0	--
90	--	--	0.1	0.2	--	2.2	0.4
120	--	0.6	3.1	--	--	1.4	0.1
150	0.2	0.2	0.0	0.1	0.2	0.0	0.1
			Site 2				
15	0.3	0.5	2.9	2.5	--	4.8	--
30	0.3	0.1	3.3	0.8	3.0	8.6	0.8
60	0.1	0.2	0.2	--	--	1.6	0.1
90	1.6	0.2	0.1	0.7	--	2.4	--
130	0.3	0.2	0.1	0.0	0.2	3.4	0.1
150	0.1	0.2	0.2	0.0	1.2	2.3	0.1

* See Table 3.

NO_3^- concentrations in the water table. The soil water samples obtained from the 150-cm depth came from the water table from June to Nov. both years. No NO_3^- concentrations higher than 2 ppm were found in any samples at the 150-cm soil depth. Leaching losses and crop recovery of N accounted for only part of the applied N, therefore, a large part of the N applied in the waste water during two processing seasons remained unaccounted for.

In conclusion, the application of potato processing waste water on agricultural land appeared to be an excellent method of disposal. Recovery of part of the applied nutrients in a grass crop that was harvested and used for livestock feed decreased the potential for on-site pollution. Nitrate concentrations in the extracted soil water samples were very low, indicating that in this properly managed treatment field NO_3^- pollution of ground water was not a major hazard.

LITERATURE CITED

1. American Public Health Association, Inc. 1971. Standard methods for the examination of water and wastewater. 13th ed. New York. 874 p.
2. Anderson, D. J., and A. T. Wallace. 1971. Innovations in industrial disposal of steam peel potato wastewater. Pac. Northwest Ind. Waste Manage. Conf. Proc. Univ. of Idaho, Moscow. p. 45–61.
3. Bell, J. W. 1955. Spray irrigation for poultry and canning waste. Public Words 86(9):111–112.
4. Bolton, P. 1947. Cannery waste disposal by field irrigation. Food Packer 38:42–43, 46.
5. Drake, J. A., and F. K. Bier. 1952. Vegetable canning waste disposal by irrigation in Minnesota. Sewage Ind. Wastes 24: 803–804. Abstr. from Proc. 6th Ind. Waste Conf. Eng. Bull. 35:6 Ext. Ser. No. 76, Purdue Univ. (Oct. 1951). p. 70–79.
6. Fisher, H. D., and J. H. Smith. 1975. An automatic system for sampling processing waste water. Soil Sci. Soc. Am. Proc. 39:382–384.
7. Luley, H. G. 1963. Spray irrigation of vegetable and fruit processing wastes. J. Water Pollut. Contr. Fed. 35:1252–1261.
8. Pearson, G. A., W. G. J. Knibbe, and H. L. Worley. 1972. Composition and variation of waste water from food processing plants. USDA, ARS 41-186. 10 p.
9. Shannon, S., M. T. Vittum, and G. H. Gibbs. 1968. Irrigation with waste water from processing plants. Res. Circ. No. 10, New York State Agric. Exp. Sta., Geneva, N. Y. 9 p.
10. Smith, J. H. 1974. Decomposition in soil of waste cooking oils used in potato processing. J. Environ. Qual. 3:279–281.
11. Thomas, R. E., and J. P. Law, Jr. 1968. Soil response to sewage effluent irrigation. p. 5–19. *In* C. W. Wilson and F. E. Beckett (ed.) Municipal sewage effluent for irrigation. Louisiana Tech. Dep. Agric. Eng., Ruston, La.
12. Wilcox, L. F. 1959. Effect of industrial waste on water for irrigation use. Am. Soc. Test. Mater. Spec. Tech. Publ. 273: 58–64.