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Microbiological Quality of Subsurface Drainage Water from Irrigated Agricultural Land[1]

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ABSTRACT

Irrigation and subsurface drainage waters sampled from an 82,150-hectare (203,000-acre) irrigation district in southern Idaho were evaluated for bacteriological quality. The soils in the district are wind deposited over fractured basalt, calcareous, and have a pH near 7.8. Drainage, where needed, is provided by horizontally mined tunnels or by tile drains connecting shallow relief wells that flow the year around. For the 12 months ending September 30, 1969, a 2-meter (6.5-foot) depth of water for the entire irrigation tract was diverted, and 50% of the water passed through the soil becoming subsurface drainage. The irrigation water and seven subsurface drains were sampled at 2-week intervals during the summer of 1969. Coliform, fecal streptococci, starch hydrolyzers, and bacteria able to grow at temperatures from 0 to 55C were counted. The diverted irrigation water contained from 140 to 3,300 coliform per 100 ml, but 86% of the subsurface drainage samples contained 5 or fewer coliforms per 100 ml. Numbers of other microorganisms were also low in the drainage waters. The outflow samples were oxygen saturated and the temperatures were 13.0 ± 1.1C for all samples. Percolation through the soil improved the water quality almost to domestic water standards.

Additional Index Words: pollution control, water purification, ground water.

Water diverted from the Snake River in southern Idaho for irrigating agricultural land is contaminated with coliforms and other microorganisms normally associated with human pollution (7). This contamination originates from sewage outfalls and food processing wastes upriver. The coliform count occasionally exceeds standards for swimming and other body contact sports, but it has not been determined that a health hazard for agricultural uses exists. In a survey of water use on the Twin Falls irrigation district during 1969, Carter, Bondurant, and Robbins (3) determined from measurement of water diverted, rainfall, surface drainage, and calculated evapotranspiration, that about 50% of the input water, or 100 cm passed through the soil and emerged from subsurface drains.

Portneuf silt loam is the predominant soil in the irrigation district. It is well drained and the nearly level phase is typical of the series, although the slope ranges from 0 to 12% with an estimated 50% of the land sloping less than 3% and 30% sloping from 3 to 6%. The depth of bedrock is over 1 m and the parent material is Aeolian (silt). Soil permeability is moderate, ranging from 2 to 6 cm/hour. Typical ranges in mechanical analyses are 15 to 20% clay, 55 to 65% silt, and 15 to 30% very fine sand (0.1 to 0.05 mm). Cation exchange capacity is approximately 21 meq/100 g soil and is made up of calcium 12, magnesium 5, sodium < 1, potassium 0.5, and hydrogen 3 meq/100 g soil. Characteristic of much of the soil is a lime-cemented hardpan approximately 35 to 50 cm below the surface. Bedrock is undecomposed basalt that is fractured, and interlayered with cinders and ash that acts as a reservoir and conveyance for a large volume of water. Wet spots are drained by horizontal tunnels mined in the basalt ranging in length from 0.4 to 3.2 km, or by shallow relief wells connected below the surface of the soil with tile drains. These tunnel and tile drains generally flow the year around, with an annual flow cycle.

Filtration has been used for years for purification of domestic water supplies. Soil infiltration for ground water recharge and sewage effluent purification on a small scale is being studied by Bouwer in Arizona (2). The domestic water supply for all of the rural residents and the small towns in the irrigation district, and part of the water used by the city of Twin Falls, comes from the aquifer. All or nearly all of the water in the aquifer is supplied from irrigation water that has passed through the soil. Most of the soil in the Twin Falls irrigation tract is deep and fertile. However, in some areas, which overlie undulating basalt, the soil is thin and occasional sinks develop. Even though incursions of irrigation water through the sinks may be infrequent, the microbiological quality of the ground water may be questionable.

The coliform bacteria content of water indicates its microbiological quality. Because coliform die-away rates closely parallel or exceed those of enteric pathogens under a variety of environmental conditions and in many treatment processes, the density of most enteric pathogens may be estimated by the density of the coliform group organisms (4). Geldreich and Kenner (5) indicated that pollution sources could be determined by observing the fecal streptococci types *S. bovis* and *S. equinus* subgroups, which are not associated with human wastes. Their presence may be used as a specific indicator of grazing animals, feedlot, or meat-processing wastes in water. Use of the fecal coliform/fecal streptococcus ratio may be an indicator of the source of pollution. Ratios less than 1 indicate nonhuman sources, and ratios greater than 2.5 indicate human pollution (8).

This research was conducted to determine the number of organisms in several microbial groups associated with water diverted for irrigation, and to determine the influence of percolation of this water through the soil on the microbial population in the ground water.

MATERIALS AND METHODS

Water samples were obtained mostly at 2-week intervals in sterile BOD bottles from the following locations shown in Fig. 1: *(1)* Snake River at Milner diversion to the Twin Falls canal, *(2)* Murtaugh Lake outlet, *(3)* Tolbert tunnel, *(4)* Padget tunnel, *(5)* Harvey tunnel, *(6)* Molander drain, *(7)* Herman tunnel, *(8)* Griffeth drain, and *(9)* State fish hatchery tunnel. These tunnels and drains were selected because they were generally free from farmyard and cattle pollution, readily accessible for sampling, located on land representative of typical agricultural areas in the irrigation district, and flowed fairly large amounts of water. Presumptive, confirmed, and completed coliform counts were made according to standard methods (1). Dilution plate counts, made on plating agar, were incubated in triplicate at 55, 35, 20, and 0C. Fecal streptococci were enumerated by micropore filtration and incubating the filters on KF agar for 48 hours. Dilutions similar to those used in the pre-

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semptive coliform test were used for starch hydrolysis determinations. Five individual drops of the water sample and serial dilutions were placed on starch agar plates and incubated at 35C for 48 to 72 hours then stained with iodine solution. Numbers of starch hydrolizers were estimated by MPN technique. Dissolved oxygen and BOD determinations were made on water samples using an oxygen analyzer with a gold-silver electrode. Water temperatures were determined to the nearest 0.1C with a glass thermometer at each site at the time of collection. Flow measurements were made at the sampling sites using standard wiers or standard current metering practices.

RESULTS AND DISCUSSION

Flow data for the sampling sites are summarized in Table 1. Maximum diversion from Milner occurred during May, July, and August, and it was assumed that the flow at Murtaugh Lake Outlet would be similar to that at Milner minus seepage loss. Peak flows from the drainage sites lagged the beginning of irrigation by 5 or 6 months. The flow of the tunnels and tile drains peaked in August and September, with the peak flow occurring earlier for those in the east end of the irrigation district than for those in the west end. Total drainage from the seven sampled sites represents approximately 6.5% of the total subsurface drainage from the irrigation district.

The maximum, minimum, and median numbers of coliform bacteria in irrigation and subsurface drainage water samples are given in Table 2. The median values are presented rather than mean values because a single incident that produced a high count would have disproportionate influence on mean values. Median values indicate the relative coliform density in each series of samples for a sampling site. The irrigation water sampled at Milner during 4 of the 10 samplings contained more than 1,000 coliform (completed test) per 100 ml water. One thousand coliform per 100 ml water has been set as an average maximum permissible for body contact sports as reported by McKee and Wolf (6) and by a USDI publication (7). More recently, the National Technical Advisory Committee on Water Quality recommends a geometric mean of 200 fecal coliforms/100 ml. Median or mean organism counts are used in determining water quality in relation to established standards. The diverted irrigation water and the effluent from Murtaugh Lake contained fairly large numbers of coliform bacteria. The subsurface drainage water on the other hand, had much lower coliform densities than did the irrigation water. The maximum number of coliform organisms in a particular sample from each of the drains was greater than water quality standards for domestic use where standards are set at less than 2.2 coliform/100 ml water (1), although 39% of the samples from all the drains were free of coliforms (completed test).

Table 1—Water measurements on irrigation canal and subsurface drains for Oct. 1, 1968 to Sept. 30, 1969

Sampling sites	Flow rate: Maximum		Minimum		Total flow for year	
	liters/sec	Date	liters/sec	Date	$M^3 \times 10^4$	Acre-feet
			Irrigation Canal			
Milner	109,866				159,119	1,290,000
			Subsurface Drains			
Tolbert tunnel	306	9/7	201	4/10	805	6,530
Padget tunnel	595	10/1	254	4/10	3,469	28,125
Harvey tunnel	606	9/4	212	2/27	1,299	10,532
Molander drain	119	10/6	31	4/21	207	1,679
Herman tunnel	263	10/21	110	4/21	628	5,090
Griffeth tunnel	82	7/30	40	4/10	202	1,640
State Fish Hatchery tunnel	314	9/5	28	4/10	559	4,533

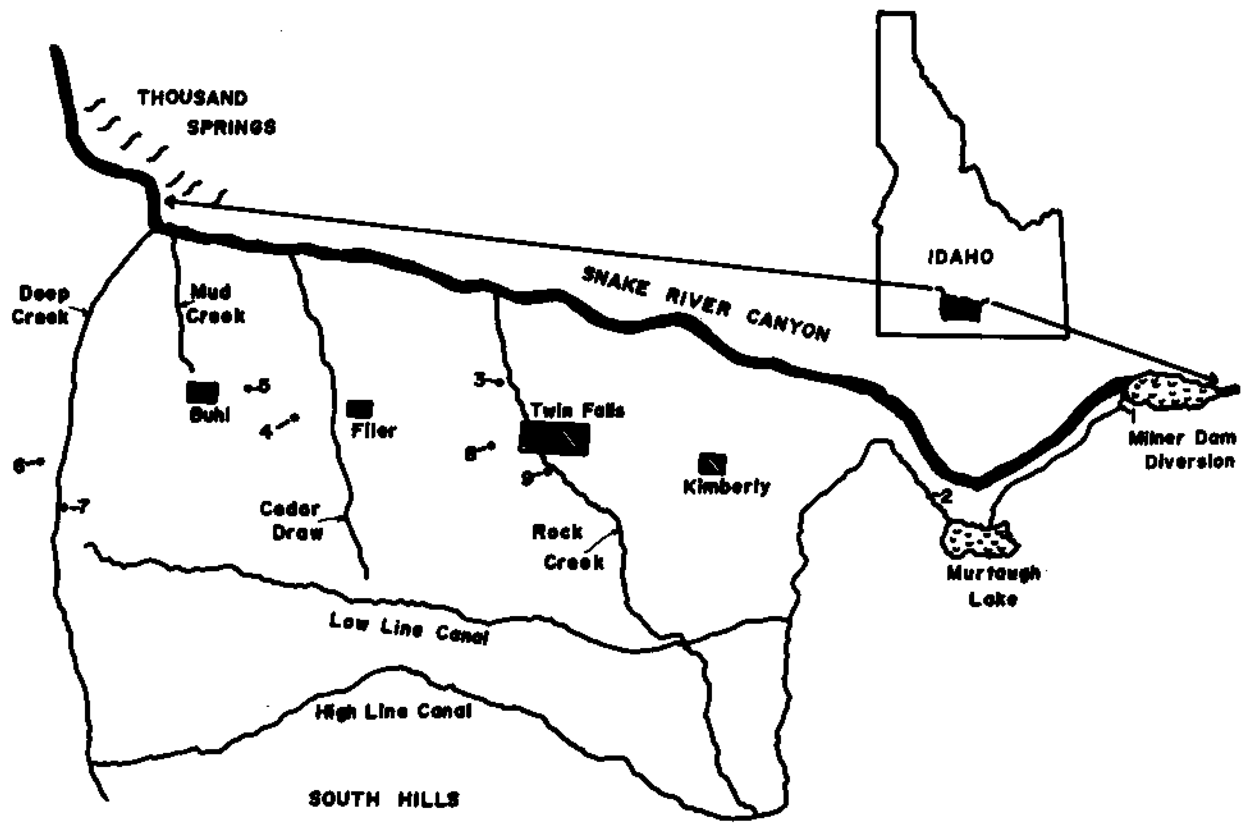

Fig. 1—Twin Falls Canal Company irrigation district. Numbers on figure correspond to water sampling sites described in the text.

Table 2—Coliform counts of irrigation and subsurface drainage water

Sampling sites	MPN organisms per 100 ml water: Maximum	Minimum	Median	No. of samplings
		Irrigation Water		
Milner	3,300	140	400	10
Murtaugh Lake outlet	2,300	200	1,400	8
		Subsurface Drainage Water		
Tolbert tunnel	8	0(7)*	0	12
Padget tunnel	11	0(2)	5	9
Harvey tunnel	5	0(4)	4	9
Molander drain	221	0(1)	14	11
Herman tunnel	5	0(6)	0	12
Griffeth tunnel	17	0(5)	0	12
State Fish Hatchery tunnel	17	0(4)	0	9

* Number in parenthesis indicates the number of samples with no coliform organisms.

Table 3—Fecal coliforms, fecal streptococci, and starch hydrolyzers in irrigation and subsurface water.

Sampling sites	MPN organisms per 100 ml water: Fecal coliform			Fecal streptococcus			Starch hydrolyzers			No. of samplings
	Max.	Min.	Median	Max.	Min.	Median	Max.	Min.	Median	
					Irrigation Water					
Milner	1,400	0(3)*	200	1,311	18	94	>321,000	10,000	44,000	10
Murtaugh Lake outlet	800	0(2)	200	370	16	100	164,000	400	34,000	8
					Subsurface Drainage Water					
Tolbert tunnel	5	0(9)	0	50	0(6)	1	0	0(12)	0	12
Padget tunnel	5	0(6)	0	2,061	0(1)	7	400	0(8)	0	9
Harvey tunnel	2	0(8)	0	3	0(2)	1	0	0(9)	0	9
Molander drain	542	0(2)	5	1,378	1	28	6,600	0(6)	0	12
Herman tunnel	5	0(8)	0	22	0(4)	2	800	0(10)	0	12
Griffeth tunnel	17	0(7)	0	65	0(2)	7	1,000	0(7)	0	12
State Fish Hatchery tunnel	17	0(5)	2	50	0(3)	1	0	0(9)	0	9

* Number in parenthesis indicates the number of samplings with no microorganisms of the types listed.

Table 4—Plate counts of microorganisms from irrigation and subsurface drainage water incubated at 55, 35, 20, and 0C

Sampling sites	Incub. temp, °C	Organisms per ml water: Maximum	Minimum	Median	No. of samplings
		Irrigation Water			
Milner	55	27	8	17	9
	35	100,000	2,000	14,000	10
	20	721,000	3,000	24,000	10
	0	2,340	40	52	4
Murtaugh Lake outlet	55	29	4	14	8
	35	39,000	1,000	7,000	7
	20	29,000	3,000	11,000	8
	0	147	23	137	4
		Subsurface Drainage Water			
Tolbert tunnel	55	5	0	1	12
	35	343	1	3	12
	20	247	0	13	11
	0	76	0	1	9
Padget tunnel	55	9	0	1	9
	35	193	0	53	9
	20	1,387	43	130	9
	0	87	0	9	8
Harvey tunnel	55	3	0	1	9
	35	68	0	4	9
	20	146	10	14	9
	0	60	1	5	6
Molander drain	55	63	0	4	11
	35	8,000	0	90	11
	20	32,200	33	333	11
	0	613	3	84	9
Herman tunnel	55	9	0	2	12
	35	61	0	6	12
	20	2,657	0	13	11
	0	63	0	2	9
Griffeth tunnel	55	20	0	1	12
	35	380	0	37	12
	20	327	28	53	11
	0	11	0	4	9
State Fish Hatcher tunnel	55	9	0	1	9
	35	300	2	8	9
	20	1,041	6	16	9
	0	30	1	4	8

Fecal coliform counts were performed by MPN analyses according to standard methods (1). Most of the surface irrigation water samples were polluted with fecal coliform bacteria (Table 3). Ground water from the drains was generally free of coliform organisms. However, at one sampling water from Molander drain contained 542 fecal coliforms/100 ml water—probably because surface water got into the drain without being adequately filtered through the soil. Soil sediment was seen in the water at this sampling. All the other drain samplings contained few coliform organisms, with 61% of the samples containing no fecal coliforms.

Fecal streptococci counts were made on all the water samples. These organisms are classified as "Lancefield's group D Streptococcus," and are generally found in the intestine of warmblooded animals. This test is somewhat more conclusive in assessing pollution from animals than the coliform count, but there is no established standard for evaluating pollution using the fecal streptococci. The irrigation water samples were polluted with fecal streptococci, with numbers ranging from 16 to 1,300 organisms/100 ml water (Table 3). Two drainage samples contained more fecal streptococci than the irrigation water, one at Padget tunnel and one at Molander drain. All of the other maximum concentrations were lower than the maximum values in the irrigation water by severalfold. Approximately 24% of the drainage samples contained no fecal streptococci.

Fecal coliform/fecal streptococci ratios were calculated on all the irrigation and drainage water samples. In the irrigation water sampled at Milner and Murtaugh Lake outlet, 10 samples had ratios less than 1. The ratios in the remaining 18 samples ranged from 2.2 to 58, indicating that human pollution was predominant in 45% of the irrigation water samples. Both fecal coliform and fecal streptococci counts were low in most of the subsurface drain samples, with many samples containing no organisms of these types. The ratios are therefore not very meaningful, although most of the ratios were less than 1. Filtration of the water removed most of the pollution from the water.

Another group of microorganisms enumerated in the water samples was the starch hydrolyzers. Water in the Snake River is used for upstream disposal of potato processing wastes (7). The presence of starch substrate stimulates buildup of bacteria utilizing the substrate. Water samples taken from Milner diversion periodically showed high numbers of these organisms (Table 3). Subsurface drainage samples were low in starch hydrolyzers with the exception of an occasional incursion of surface water into the shallow Molander drain and the Griffeth tunnel. Three of the tunnels had no starch hydrolyzers in any of the samples, and 81% of the subsurface drainage samples contained no starch hydrolyzers. The cleanup through soil filtration effectively removed these microorganisms.

A comparison was made of the number of thermophilic, mesophilic, and psychrophilic microorganisms in the irrigation and subsurface drainage water samples (Table 4). These determinations were included to broaden the scope of the experiment to indicate the extent of filtration cleanup of these groups of microorganisms. Numbers of psychrophiles and thermophiles were lowest in all the water samples, but a few organisms capable of growing at

5U or 0C were found in most of the samples. The greatest numbers of microorganisms had an optimum of 20C with 35C being the next most favorable temperature. Total counts in the irrigation water samples were fairly high with counts up to approximately 700,000/ml in the highest count Milner water sample. The highest count found at Murtaugh Lake was less than 10% of that at Milner. Filtration decreased the total counts of organisms in the subsurface drainage water with maximum counts in the drains being approximately 3% as great as in the irrigation water at Murtaugh Lake. The median and minimum values in the drains were less than 0.3% as great as in the irrigation water at Murtaugh Lake. The number of samplings shown in Table 4 are different for some of the temperatures. Some difficulties in making the counts were encountered because some dilutions were not in the appropriate range. The greatest difficulty was encountered with samples incubated at 0C.

Temperature of the irrigation water ranged from 9.8 to 22.4C during the irrigation season. The subsurface drainage water temperature was relatively constant with all samples being 13.0 ± 1.1C for all locations and sampling dates. All of the water samples were saturated with oxygen at every sampling. Biochemical oxygen demand (BOD_5) for the irrigation water was generally in the range of 1 to 5 mg oxygen per liter of water. The subsurface drainage samples had a lower BOD than the irrigation water with most samples having no oxygen demand. The removal of BOD_5 through soil filtration correlates with fecal coliform and fecal streptococci removal and with improved water quality.

CONCLUSION

The irrigation water was consistently polluted with microorganisms associated with fecal waste, as indicated by numbers of organisms and by fecal coliform/fecal streptococci ratios. Approximately 50% of the irrigation water infiltrated the soil and emerged from subsurface drains. Filtration greatly decreased the microorganism populations studied and also decreased the indicator bacteria to levels acceptable for domestic use of the water in many cases. Even though occasional sinks develop and pose some question about consistent filtering of water through the soil, the microbiological quality of the subsurface drainage water from this large irrigation district is vastly improved over the irrigation water quality.

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