THE EFFECT OF SO_2 TREATED WATER ON AN AQUATIC INSECT POPULATION

by

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August 1976

INTRODUCTION

A Department of Ecology representative attended a meeting scheduled by the U.S. Bureau of Reclamation to discuss the reclamation of buried tile drain in block 72, unit 344 of the Columbia Basin Project and the subsequent discharge of treated drain water to irrigation canal W654W.

The drains, over the years since installation, had become clogged with iron and manganese compounds and were no longer providing proper drainage of soil water. It was proposed by the U.S.B.R. to plug the drains and inject sulfur dioxide (SO_2) to dissolve the manganese and iron compounds and unclog the drains. The discharge water, in addition to naturally occurring mineral compounds, would contain sulfurous and sulfuric acids according to equation:

$$SO_2 + H_2O \rightarrow H_2SO_3 + O_2 \rightarrow H_2SO_4$$

sulfur dioxide	water	sulfurous acid	oxygen	sulfuric acid

The injected SO_2 would react with the drain water to produce H_2SO_3 which in turn would react with any available oxygen contained in the drain water to produce H_2SO_4.

Questions were raised at the meeting regarding detrimental effects of the discharge water constituents. Obviously the waste water would be acid, contain a reduced quantity of oxygen and could have toxic effects on the aquatic biota.

The Department of Ecology agreed to cooperate with the Washington State Department of Game, the U.S. Fish & Wildlife Service, and the U.S.B.R. to conduct a water monitoring program. Initially the Department of Ecology agreed to furnish the U.S. Fish & Wildlife Service with equipment to conduct a before and after assessment of the aquatic insect population. If this biological community were affected, it was reasoned, the sport fishery that existed in the canal may also be affected. As it turned out, the Department of Ecology conducted the aquatic insect investigation plus measuring sulfurous acid concentrations and conducted some pH determinations.

METHODS

The investigation was conducted in two phases. The first phase was a reconnaissance survey to become familiar with the survey area and to collect some data before the reclamation of the drain tile began. The second phase was collection of data during the discharge of the drain waste water to the irrigation canal. Aquatic insects were measured during both phases of the study. Aquatic insects were selected as the test organisms rather than fish since they are easy to collect, widely distributed and abundant particularly in shallow waters such as existed in W645W, are very sensitive to pollutants, and are less mobile than larger aquatic organisms. During the first phase of the project the general chemistry of the water was determined while in the second phase most attention was directed to the measurement of sulfurous acid.

Aquatic Insects

Two different types of equipment were used to collect aquatic insects, a drift net and a Surber sampler. The drift net was used during the reconnaissance survey to get an estimate of the insect population at several points within canal W645W. The net was anchored in the stream, then a 2' X 15' area was disturbed upstream of the net with a large number of the dislodged insects being captured by the net. This was repeated a second time, after which the samples were combined and preserved for later identification and enumeration. During the discharge of the treated drain water the drift net was again used but in a different way. It was anchored in the stream but the area upstream was not disturbed and it was left in the stream for a period of exactly one minute. The purpose of this experiment was to collect insects that possibly were being killed or otherwise dislodged from the bottom substrate as a result of toxic effects of the drain water.

The Surber sampler, similar to the drift net, was used to quantify the insect population, but because an exact area (1 sq. ft.) is used and 100% of the insects are collected, it is a much more precise method. It was used at the end of the survey, above and below the discharge point, to determine as accurately as possible, if the population had been reduced as a result of toxic effects of the treated drain water.

Sulfurous Acid

Sulfurous acid analyses were originally to be conducted by U.S.B.R., however, a factory ordered test kit did not arrive in time to be used on the project. On the day of the survey a method was developed by the Department of Ecology to analyze for sulfurous acid. Test chemicals were taken from a Winkler dissolved oxygen test kit.[(1)] A iodometric titration was performed using the following procedure: 1) To a 200 ml sample approximately 2 ml of alkali-iodide-azide reagent was added; 2) The sample was then acidified using approximately 2 ml concentrated sulfuric acid; 3) Portions of exactly 2 ml each of standard potassium biniodate 0.025N were added until a characteristic iodine color persisted in the sample solution; 4) The iodine solution was then titrated against .025N sodium thio sulfate using starch indicator. Sulfurous acid was calculated using the following formula:

$$\frac{(\text{ml biniodate} - \text{ml sodium thio sulfate}) \times 0.93 \times 1000}{\text{ml sample}} = H_2SO_3 \text{ mg/l}$$

1) ml biniodate is subtracted from ml sodium thio sulfate to obtain the actual ml of biniodate required.

2) 0.93 is a factor used to convert ml biniodate to mg sulfurous acid (see Appendix).

3) 1000 in the numerator and ml sample in the denominator converts mg H_2SO_3 to mg/l H_2SO_3

(1) Standard Methods for the examination of Water and Wastewaters American Public Health Assn. Inc., 1790 Broadway, N.Y., 19, N.Y. 13th Edition, p. 477

RECONNAISSANCE SURVEY

On October 17, 1975 the project area was visited to gain a familiarization with the survey area, to assess the abundance of aquatic insects in the irrigation canal and to determine the chemical characteristics of both the drain and canal water prior to the use of SO_2.

Insect samples were collected at four stations: a, e, f and h (see map, page). A healthy and diverse insect population existed in the canal above and below the drain discharge point (Table 1).

Table 1. Aquatic insects collected from Columbia Basin Project irrigation canal W645W on October 17, 1975.

Sta.	Ephemeroptera (mayflies)		Plecoptera (stone-flies)		Diptera (two-winged flies)		Tricoptera (caddis-flies)		Coleoptera (Beetles)		Other		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
a	176	45.6	0	0.0	20	5.9	80	26.8	72	16.0	18	4.9	366
e	284	42.8	0	0.0	18	2.1	34	19.4	214	32.9	14	2.4	564
f	252	44.5	0	0.0	36	6.8	172	30.1	80	14.9	20	3.5	560
n	486	51.5	1	0.3	45	5.3	208	24.4	146	15.5	17	1.8	903

The population make-up appeared to be similar at all four stations as indicated by the percentage values. The fact that the total number varied from station to station was felt to be of little significance and was primarily attributed to the method of collection.

Field and laboratory analysis of water samples collected from the canal and drain revealed water which was more or less typical for an irrigation canal system.

Table 2. Chemical analysis and estimated flow for Columbia Basin Project irrigation canal W645W and a drain discharging to the canal. Sample collected on October 17, 1975

Tests*	Stations		
	a	3a	e
Flow (cfs)	4.5	0.1	4.5
Temperature °C	13.0	--	--
Dissolved Oxygen	10.4	8.7	10.4
pH (SU)	8.8	7.9	8.8
Turbidity (JTU)	12.0	5.0	15.0
Calcium	28.0	50.0	29.0
Magnesium	20.0	31.0	22.0
Manganese	<0.05	< 0.05	< 0.05
Iron	0.20	< 0.05	0.20
Bicarbonate	230.0	280.0	240.0
Chloride	16.0	18.0	14.0
Sulfate	5.0	21.0	3.0
Sodium	43.0	63.0	44.0
Potassium	10.7	3.8	11.0
Nitrate nitrogen	2.8	9.3	3.2
nitrite nitrogen	ND**	ND	ND
Ortho phosphate as P	0.26	0.04	0.27
Total phosphate as P	0.36	0.12	0.38

* mg/l unless otherwise noted
** none detected.

The water had sufficient nitrates, phosphates and minerals to support a substantial plant and animal population. By comparison the ortho-phosphate concentrations and nitrate concentrations for clean water streams is generally less than 0.1 mg/l and 1.0 mg/l respectively. Algae and other green plants were growing in the canal as evidenced by dissolved oxygen and pH concentrations. In the absence of green plants the dissolved oxygen would probably have been less than 10.0 and the pH less than 7.5. It can be seen that concentrations of both these parameters are lower in the drain water since green plants would exist only in the open ditch portion of the drain and did not affect its water quality significantly.

Two parameters of particular importance to this study are the ratio of the canal flow to the drain flow and the bicarbonate concentration in the canal water. The favorable dilution ratio of 45:1 would help to minimize the effect of drain water quality on the water quality of the canal. The bicarbonate concentration which was 2 to 3 times higher than normally found in clean rivers and would buffer the water against any sudden or large pH change. Since the treated drain water was expected to be acidic (have a low pH) and generally have a reduced quality, these would both be effective in minimizing the effect of SO_2 drain water on the water quality of the canal.

DISCHARGE OF TREATED WATER

The first release of SO_2 treated water occurred at approximately 1017 on October 24, 1975. Insect and water samples were collected alternately from 0935 until 1700 to measure the environmental impact of the discharge water on the canal.

Sulfurous Acid

The first sign of sulfurous acid was measured in the canal at 1025 (See Table 3). It increased to 20.5 mg/l by 1113. With the increased concentration of sulfurous acid the pH and dissolved oxygen of the drain water declined. Of particular interest is the dissolved oxygen concentration. As noted on Page 1, the O_2 is consumed as the sulfurous acid is converted to sulfuric acid. This chemical reaction apparently reduced the oxygen concentration from 8.7 mg/l measured during the reconnaissance survey October 17, 1975 to 1.1 mg/l at 1113 then to 0.7 mg/l at 1530.

Fortunately the sulfurous acid concentration remained relatively low in the canal, if it had not, a serious oxygen depletion might have occurred there as well.

Table 3. Analysis of water samples collected on October 24, 1975 from the Columbia Basin Project irrigation canal W645W and a drain discharging to the canal

Station	Time	Temp (^{o}C)	DO (mg/l)	pH (SU)	H_2SO_3 (mg/l)
3	935	--	--	--	0.0
c	1017	11.0	9.1	8.6	0.0
c	1025	12.0	9.2	8.6	0.5
3	1035	13.0	3.7	7.3	0.5
3	1113	13.0	1.1	6.7	20.5
3	1530	14.0	0.7	6.6	>9.3*
e	1600	12.0	10.4	8.7	0.9

* Insufficient supply of biniodate reagent. For this reason only one more test was conducted.

Aquatic Insects

Shortly after sulfurous acid was first observed in the canal water a drift net was placed in the canal at station e to capture any insects being affected by the treated waste water and hence drifting downstream. Because of debris in the stream the drift was limited to 1 minute. Four insects were collected in which all four appeared to be in good health (see Table 4).

Table 4. Aquatic insect samples from the Columbia Basin Project irrigation canal W645W. Samples collected using a drift net for a period of 1 minute.

Sta.	Time	Ephemeroptera		Plecoptera		Diptera		Tricoptera		Coleoptera		Other		Total
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
e	1100	0	0.0	0	0.0	1	25.0	1	25.0	0	0.0	2	50	4
k	1200	0	0.0	0	0.0	0	0.0	0	0.0	1	25.0	4	80	5

A second drift was conducted, using an identical method and drift time, at station k upstream of the drain discharge point. Five insects were collected. Since the data from the two stations were virtually the same it did not appear that the insect population was being significantly impacted at that time and that the captured insects were merely the result of normal insect movement within the canal.

Later, after treated drain water had been discharged for a period of over 5 hours a precise quantification of the insect population was conducted using the Surber sampler. Two samples were collected, above and below the discharge point (see Table 5).

Table 5. Aquatic insect samples from the Columbia Basin Project irrigation canal W645W. Samples represent one square foot of canal bottom area.

Sta.	Time	Ephemeroptera		Plecoptera		Diptera		Tricoptera		Coleoptera		Other		Total
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
a	1700	12	8.3	0	0	2	1.4	68	46.9	63	43.4	0	0	145
c	1645	15	11.8	0	0	3	2.4	53	41.7	54	42.5	2	1.6	127

The two samples appeared to be very similar both in terms of diversity and total number of insects present.

CONCLUSIONS

1. Tile drain water treated with SO_2 has a reduced pH and a very low oxygen content.

2. Aquatic insects can live in water containing up to .9 mg/1 H_2SO_3 for a period of 5 hours without any apparent ill effects.

3. It appears that reclamation of buried tile drains with subsequent discharge of SO_2 treated waste water can be carried out with little impact on the aquatic insect population, however, a larger study is needed to observe the effect on the population for the full period of discharge.

APPENDIX

H_2SO_3 DETERMINATION CHEMICAL REACTIONS

The sulfurous acid determination involves a two-step reaction. First, using Winkler method reagents an iodine solution of known strength is produced according to the equation:

$$KIO_3 + 5I^- + 6H^+ = 3I_2 + 3H_2O$$

KIO_3	$5I^-$	$6H^+$	$3I_2$	$3H_2O$
biniodate	Alkaline iodide azide	Sulfuric acid	Iodine	Water

In this reaction a 1 ml solution of .025 KIO_3 (.8124 mg/ml) will produce 2.89 mg I_2.

If H_2SO_3 is present the liberated iodine will then react with the H_2SO_3 according to the equation:

$$H_2SO_3 + I_2 + H_2O = H_2SO_4 + 2H^+ + 2I^-$$

In this second reaction the previously produced 2.89 mg I_2 will react with .93 mg H_2SO_3 so that the original 1 ml of .025N KIO_3 is equivalent to .93 mg H_2SO_3. In the calculations then the factor .93 is used to convert ml KIO_3 to mg H_2SO_3.