Stream quality measurements along a livestock wintering operation
by Glenn Hagfeldt

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Agricultural Engineering
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Abstract:
Although many studies have been undertaken to see what the pollu-tional effects of large concentrations of animals in feedlots are, very little research has been done relative to livestock wintering operations. Many states, including Montana, still utilize a summer range with confine ment during the winter months. With the current emphasis on protection of the environment it was felt that research was needed to determine what the pollutional effects, if any, of these wintering operations might be.

In many cases livestock wintering operations are located near streams because of the protection from wind usually found near streams, and for ease in getting the animals to water. When the waste actually enters the environment where it could affect human lives, then it becomes important to know where the waste goes. In the case of livestock concentrated along streams the two major concerns are a buildup of some constituents of animal wastes, such as nitrates, to potentially harmful levels, and the possibility of disease transmission through the wastes.

The location of the test site was the Holmstrom Ranch located northwest of White Sulphur Springs, Montana. Through the winter of 1970-1971 there were 1100 head of sheep, 85 hogs, 185 cows, and 243 head of calves wintered along the creek.

Four water sampling stations were set up along the creek, three in the wintering area and a fourth approximately four miles upstream. Periodically samples were taken and the nitrate and chloride ion concentrations were recorded using a specific ion meter. Conductivity, sample temperature, stream flow, and weather conditions were also recorded. The testing indicated the concentrations of nitrate and chloride ion were very small, much less than the upper limits allowed by the United States Public Health Service. The readings were also consistently the same during the project. Because the levels were so low, the actual concentrations could not be determined using the equipment and techniques available. Averaging all the readings taken over the project period (April 1 to May 18) did indicate that both nitrate and chloride ion decreased slightly along the wintering area. It was felt that more testing was needed to determine if these paramenters did actually decrease, or if this was a result of the testing methods used.

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STREAM QUALITY MEASUREMENTS ALONG A LIVESTOCK WINTERING OPERATION

GLENN HAGFELDT

ABSTRACT

Although many studies have been undertaken to see what the pollutional effects of large concentrations of animals in feedlots are, very little research has been done relative to livestock wintering operations. Many states, including Montana, still utilize a summer range with confinement during the winter months. With the current emphasis on protection of the environment it was felt that research was needed to determine what the pollutional effects, if any, of these wintering operations might be.

In many cases livestock wintering operations are located near streams because of the protection from wind usually found near streams, and for ease in getting the animals to water. When the waste actually enters the environment where it could affect human lives, then it becomes important to know where the waste goes. In the case of livestock concentrated along streams the two major concerns are a buildup of some constituents of animal wastes, such as nitrates, to potentially harmful levels, and the possibility of disease transmission through the wastes.

The location of the test site was the Holmstrom Ranch located northwest of White Sulphur Springs, Montana. Through the winter of 1970-1971 there were 1100 head of sheep, 85 hogs, 185 cows, and 243 head of calves wintered along the creek.

Four water sampling stations were set up along the creek, three in the wintering area and a fourth approximately four miles upstream. Periodically samples were taken and the nitrate and chloride ion concentrations were recorded using a specific ion meter. Conductivity, sample temperature, stream flow, and weather conditions were also recorded. The testing indicated the concentrations of nitrate and chloride ion were very small, much less than the upper limits allowed by the United States Public Health Service. The readings were also consistently the same during the project. Because the levels were so low, the actual concentrations could not be determined using the equipment and techniques available. Averaging all the readings taken over the project period (April 1 to May 18) did indicate that both nitrate and chloride ion decreased slightly along the wintering area. It was felt that more testing was needed to determine if these paramenters did actually decrease, or if this was a result of the testing methods used.

INTRODUCTION

Public concern for the protection and wise management of our environment has increased within the last few years. Many areas of our economy which have been ignored over the years are now being re-evaluated.

Cattle feedlots have been increasingly under attack over the last several years. Many states, including Montana, have been attempting to formulate regulations in order to control the pollution caused by the confinement of animals, yet be equitable enough to allow the rancher to continue his business without undue restrictions.

One of the questions that arises is how to consider wintering operations. Montana is a state with large amounts of rangeland and harsh winters. Many ranchers confine their animals throughout the winter in order to protect them from the weather and for convenience of feeding while the ground is covered with snow. In the case of breeding stock, this confinement may extend well into the springtime runoff period, until all animals have given birth to their young.

Working under the direction of Dr. C. M. Milne, with funding through the Montana Agricultural Experiment Station, an attempt was made to develop a program which would help determine if animal wintering operations located along streams are polluters, and if so under what conditions the pollution occurs. To begin the project it was decided to sample the water as it moved through the wintering area for evidence of animal activity. If the animal wastes were getting into the stream

in quantity, it was felt that changes in the concentration of certain constituents of the water sample would be found.

REVIEW of LITERATURE

Animal Confinement Pollution

The project's purpose was to find what effect, if any, animal wintering operations along a stream has on stream quality. Very little work has been done regarding pollution from wintering operations, and in order to give some background to the problem, the wintering operation can be considered as a semi-yearly feedlot operation. Studies on feedlots within the last few years have been conducted which will shed some light on what might be expected from wintering operations.

The confined wintering operation represents a pollution potential. Whereas domestic sewage reaches the environment in a continuous flow, wastes from confined animal units reach the environment in quantity intermittently. Although the waste comes from a single source, the results are two different wastes. First, there is the solids build up; secondly, there is the runoff that can occur over the confining area, and enter the stream. In colder regions, the potential for stream degradation is highest during periods of spring snow-melt and runoff, and during periods of rain in early spring and fall.

Wintering area location has usually been unfavorable to stream quality. The Honorable Bill Clayton of the Texas House of Representatives said, "In the not too distant past, feedlots were, by design,

situated in such a manner that wastes were allowed to run off into nearby draws or other natural drainage features. The only thought in mind was the ease in the removal and disposal of waste material." (22, p. 6)

Unfortunately, the criteria for wintering operations and feed lots are very much the same. In general, they are located close to water sources and in areas where the terrain gives good drainage and brush gives protection from the wind.

The actual volume, strength, and rate of delivery of wastes from the wintering area depends on several variables. The topographic, meteorologic, and geologic conditions effect the rate and strength of delivery of the wastes. It has also been shown that the moisture content of the manure, temperature, nature of the surface, and animal density have an effect on delivery. (14, p. 7) This would indicate that the wintering operation becomes a polluter only during periods of heavy run-off, when the wastes find their way into the water course before sufficient biodegradation has taken place.

One indication of the degree of pollution has been the feedlots' association with fish kills. The organic material from the animal wastes lowers the oxygen level of the stream to a point where most life cannot survive. Table I shows the percentage of fish kills reportedly caused by feedlots in the state of Kansas. (14, p. 10)

Table I - Fish-kills reported in Kansas 1960-1968.

KANSAS						
	Total Number Fish Kills		Total Fish Killed (mil)		% Fish Kills Attributed to Feed-lots	No. Commercial Feedlots January 1
Year	All Causes	Feed-lots	All Causes	Feed-lots		
1960	No	Report				58,000
61	4	1	No	Report		88,000
62	1	0	0.005	0	0	99,000
63	9	2	0.14	0.12	89	150,000
64	26	16	1.35	1.12	82	183,000
65	6	5	0.57	0.57	99	200,000
66	23	16	1.2	1.0	90	260,000
67	29	18	1.0	1.0	94	311,000
68	16	3	0.4	.03	7	338,000

There is no information on fish kills caused by wintering operations. This is probably because the animal densities do not approach those found in feedlots, and the tremendous shock loading required to deplete the oxygen level does not occur.

Waste Characteristics

The physical, chemical, and biological characteristics of animal wastes are difficult to determine. Animal wastes are affected by the physiology of the animal. The type of feed and environment also play a part in determining waste characteristics. Table II lists some of the parameters of animal waste for several different animals. (13, p. 12)

Table II - Suggested values for manure defecation rates per 1,000 lb. liveweight in confinement animal production.

Items	Units	Dairy Cattle	Beef Cattle	Poultry Hens	Pigs	Sheep
Raw manure (WM) ..	lb./day	88	-	59	50	37
Total solids (TS).	lb./day	9	-	17.4	7.2	8.4
	% WM	10	-	30	14.4	22.7
Volatile solids (VS)	lb./day	7.2	-	12.9	5.9	6.9
	% TS	80	80	74	82	82
BOD	lb./day	1.7	-	4.4	2.1	0.7
	lb./day VS	0.2333	0.252	0.338	0.363	0.101
BOD/COD	%	16	-	28	33	-
Nitrogen	% TS	4	9.8	11.5	5.6	-
P_2O_5	% TS	1.1	-	-	2.5	-
K	% TS	1.7	-	-	1.4	-

The percent of solids present in the waste is dependent primarily on animal type and the type and amount of feed used. Whereas municipal and industrial sewage is primarily water with some solids, feedlot wastes are characterized as solids containing some water. Although animal excrement contains a high degree of moisture, the dilution is far below the ratio of domestic sewage dilutions. This causes some problems when the attempt is made to run the traditional tests on the wastes. The BOD, COD, and suspended solids tests were developed for use with the highly liquefied domestic sewages. The waste slurries from the feedlots are highly concentrated and must be diluted before the traditional tests can be run.

After the BOD, COD, and the amount of suspended solids of the waste

are known, their value is further diminished because the wastes tested on the feedlot surface bear little resemblance to what actually finds its way into the water course.

"The feces, urine, and feed deposited on the lot undergo continuing physical, chemical, and biological change. The extent of such changes is variable from one location to another and from time to time at the same location. Natural drying may be an important factor at one location and time but not at another. Biological activity may result in considerable waste stabilization at one time, but not at another. The biological decomposition may proceed under either aerobic or anaerobic conditions, or both at different times at locations on the same feedlot." (5, p. 3)

F. B. Morrison, in his book Feeds and Feeding states, "The feces of farm animals consists chiefly of undigested food that has never really been within the body proper. This undigested food is mostly cellulose fibers, which has escaped bacterial action. A portion of the other nutrients usually escape digestion . . .

In addition to undigested food, the feces also contain residue from the digestive fluids, waste mineral matter, worn-out cells from the intestinal linings, mucus, and bacteria. They may also contain such foreign matter as dirt consumed along with the food.

Nearly all of the nitrogenous waste, resulting from the breakdown of protein material in the body, is excreted in the urine through the kidneys.

A great variety of other end-products of metabolism are likewise eliminated by the kidneys through the urine. Much of the mineral matter is excreted in the urine. However, calcium, magnesium, iron, and phosphorus are voided chiefly in the feces." (15)

The undigested material and bacterial cells account for 20-30% of the solid excrement, and this contains half or more of the nitrogen. Because animal wastes are so concentrated and heterogenous, a representative sample is very hard to obtain. (12, p. 28)

The Livestock Digestive System

The digestive system of the animal plays an important role in the waste characteristics. Non-ruminants such as swine, are called simple-stomached animals. The wastes produced by non-ruminants are similar to that of a human, with relatively small amounts of excreta produced for the amount of food consumed. (12, p. 24) The ruminants, which include cattle, sheep, and goats have a compartmented stomach. The stomach is made up of four different areas and this compartmentization allows the animal to effectively utilize the cellulose fibers of the feed, which the simpler stomached animals cannot do. With non-ruminants (simple-stomached) animals, micro-organisms seem to have only a minor role in the digestive system, whereas in the ruminants, a symbiotic relationship is formed "with micro-organisms ingested with the feed by providing a first-stomach compartment, the paunch or rumen, which is simply a large fermentation vessel . . . which results in the growth of enormous numbers

of micro-organisms, ten billion per ml of fluid." (13, p. 9)

Although the ruminant is able to handle the cellulosic feeds, the feed also contains many compounds, such as lignins, which are not digested. The net result is that the ruminant has high amounts of wastes produced per pound of feed consumed. (12, p. 25)

Because of the many differences in digestive systems and type of feed, "one must be cautious in assuming that data accumulated with one species of animals will be applicable to other species." Care must also be taken in assuming that studies made with human wastes will apply to the wastes of animals. (12, p. 26)

Disease Transmission

The high amount of micro-organisms in the ruminants stomach brings up the question of diseases and their transmission to humans from animal wastes. In Farm Animal Waste Management, edited by J. Ronald Miner, it states that livestock wastes are a potential source of infectious agents of disease that may affect animals and man by way of water and insects and, sometimes by air. Even though there have been relatively few cases where water borne diseases have been traced to animals, a few cases have occurred, and with the increase in outdoor and water-related recreation in the United States, the opportunities for exposure have been greatly increased. (13, p. 6)

Coliform bacteria can be used as indicators of contamination. The coliform group is technically defined as those aerobic and facultative

anaerobic, non-spore forming, Gram-negative, rod-shaped bacteria that ferment lactose (milk sugar) with the production at 35°C. of gas within 48 hours. (7, p. 32-28) Because coliform bacteria originate in soil and vegetation as well as the intestinal tract of warm blooded animals, the Gram stain test is an indicator of the source of the coliform.

Fair, Geyer, and Okun, in Water Purification and Wastewater Treatment and Disposal, list why the coliform bacteria do indicate contamination.

"1.) When sewage is examined for coliform organisms, about half of the lactose fermenters are found to belong to the species originating in fecal matter. Because human feces are the principal source of enteric pathogens, the finding of coliforms offers significant evidence of danger. The rate of their destruction or death, are substantially parallel to the respective rate for pathogenic intestinal bacteria.

2.) The number of coliform organisms in human feces is estimated to be between 10^{11} and 10^{13} per capita daily . . . The current U. S. Public Health Service Standards for drinking water supplied to interstate carriers set a limit of no more than one coliform organism in 100 ml or 40 coliform per gallon . . ." (7, p. 32-28)

The above statements indicate that the large numbers of coliform found in human wastes are good indicators of potential contamination from pathogenic enteric bacteria. "Whether this is so in like measure

for other disease species - the virus of infectious hepatitas for instance - remains unproved." (7,p. 32-28)

Temperature Effects on Bio-activity

Almost all bio-chemical reactions take place between the temperature range of 0-60°C. It is generally assumed that these reactions with organic matter roughly follow the Vant Hoff rule of doubling their rate for every increase of 10°C. This would indicate that waste matter from feedlots would not only accumulate during the colder periods, but also that biological activity would be at a minimum.

Standards for Water Quality

Table III is a summary of the U. S. Public Health Service Drinking Water Standards. The table includes suggested limits for some parameters, and an upper limit for rejection in some cases. (20, p. 33)

Ion-selective Electrodes and Their History

Many of the new ion-selective electrodes which have been developed within the last few years are an outgrowth of the older glass pH and sodium electrodes. Table IV gives a listing of the different electrodes currently available, and some of their properties. (8, p. 1) There are several reasons why the specific-ion electrode is ideal for water pollution monitoring. First, the electrode covers a wide range of concentration in a single instrument. Referring to Table IV, the range of magnitude of detection varies from 1 to 10^{-5} Molar (a molar contains

Table III - U. S. Public Health Service Drinking Water Standards, 1962.

Characteristic	Suggested Limit For Should Not Be Exceeded	Cause For Rejection
Physical		
Color	15 units	
Taste	Unobjectionable	
Threshold odor number	3	
Turbicity	5 units	
Chemical	mg/l	mg/l
Alkyl benzene sulfonate	0.5	
Arsenic	0.01	0.05
Barium		1.0
Cadmium		0.01
Chloride	250	
Chromium (hexavalent)		0.05
Copper	1	
Carbon chloroform extract	0.2	
Cyanide	0.01	0.2
Fluoride	0.7-1.2	1.4-2.4
Iron	0.3	
Lead		0.05
Manganese	0.05	
Nitrate	45	
Phenols	0.0001	
Selenium		0.01
Silver		0.05
Sulfate	250	
Total dissolved solids	500	
Zinc	5	

Table IV - Electrodes for water analyses.

Ion	Activity Range (M)	pH Range
calcium	10^{0}-10^{-5}	5.5-11
water hardness (divalent cation)	10^{0}-10^{-8}	5.5-11
nitrate	10^{-1}-10^{-5}	2-12
chloride	10^{-1}-10^{-5}	2-11
chloride	10^{0}-$5x10^{-5}$	0-14
cyanide	10^{-2}-10^{-4}	0-14
fluoride	10^{0}-10^{-6}	0-8.5
sulfide	10^{0}-10^{-17}	0-14

one mole of solute per liter of solution) for the calcium electrode to 1 to 10^{-17} for the sulfide electrode. Also, the response time for the electrode is within the range of several minutes at the longest, giving quick results. Little or no pre-treatment of the sample is required, making it an excellent instrument for field work. Samples as small as 15 ml can be tested, and the composition of the sample is not significantly altered from testing. Additional information regarding this type of instrument is contained in the Appendix.

STATEMENT OF PROBLEM

General Approach

If animal wintering operations are polluters, it would be desirable to develop methods that could detect this pollution. With most confined animal operations, the most concern is when these wastes enter a stream in concentrations high enough to affect human life. The best approach to the problem seemed to be to sample the stream flow near the wintering operation for constituents that might indicate animal activity.

Area Location

The area chosen was the Holmstrom Ranch owned by Robert Weitz, located approximately six miles northwest of White Sulphur Springs, Montana. Figure 1 is a map showing the location of the Holmstrom Ranch.

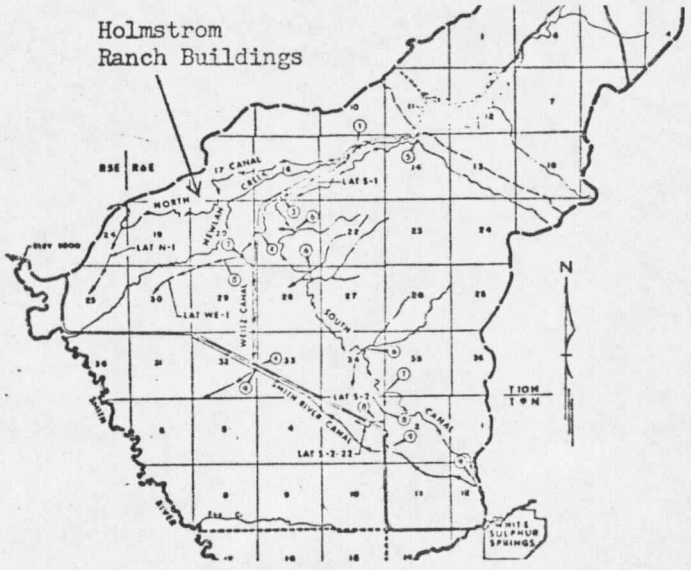

Figure 1 - Location of Holmstrom Ranch northwest of White Sulphur Springs, Montana.