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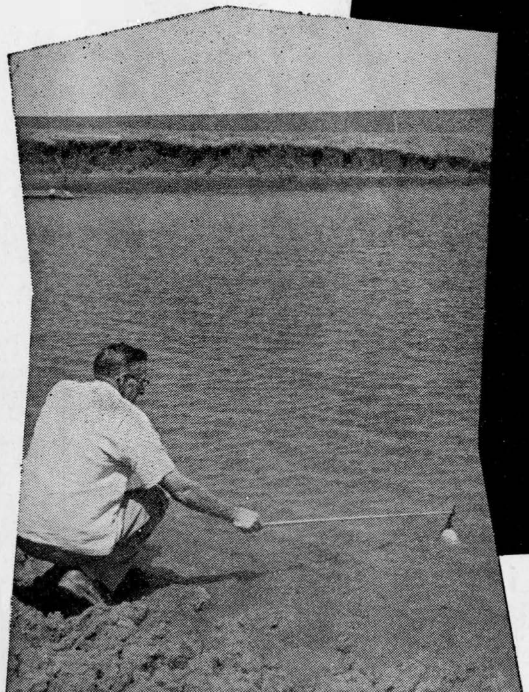

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Salinity and Livestock Water Quality

Criteria for judging the suitability of water for livestock have been suggested in the past by several sources. Often these criteria have been based on observation, although in some instances experimental work has been done to assist in their development. However, the lack of experimental work and the variation among standards that have been published made the establishment of criteria for use at this experiment station difficult. Therefore, research to assist in the development of reasonably accurate standards for livestock was undertaken.

Some have recommended that standards for livestock waters should be the same as they are for human consumption. This, however, would eliminate from use dams, dugouts, and certain other common sources because they would fail to meet bacteriological standards. In addition, animals possibly can tolerate higher salinities than can humans, and it is conceivable that they differ from man in their tolerance for certain specific substances. Actually, the standards used for water for human consumption are obviously much higher in many respects than is necessary for livestock waters.

In establishing standards for livestock waters, several factors must be considered. These include microbial contamination, presence of toxic inorganic chemicals, presence of organic toxins, accidental contamination with agricultural chemicals, alkalinity, and salinity. Of these, salinity seems to be most often involved in causing waters to be unfit for livestock in South Dakota. For this reason, the studies reported here have dealt entirely with salts or mineral content.

The tolerance of livestock and poultry toward minerals in water will depend on many things, including: kind of animal, age, season of year, climate, kind of salts in the water, physiological condition of the animal, and feed. All of these variables could not be included in the work reported here. However, rats, cattle, poultry, and swine were used and several types of salts were studied. The experiments with the different animals are reported separately.

RAT STUDIES

Experiments with albino rats were undertaken preliminary to work with large animals. The purpose here was two-fold: (1) to compare several kinds of salts and get some idea of their relative toxicities; and (2) to establish what concentrations of salts would be best used in experimental work with large animals.

Methods

Male albino rats (Sprague-Dawley) were placed on experiment at an average weight of about 68 grams. They were housed on wire

in individual cages and were allowed feed and water free choice. The temperature of the room in which they were housed was maintained at about 75-80° F. The experiment was terminated at 50 days.

The diet used for each group of rats was as follows: corn, 77.9%; casein, 15.0%; brewer's yeast, 2.0%; salts (USP XIV), 2.0%; a vitamin B_{12} concentrate (Nutritional Biochemicals Corp.), 0.1%; and cottonseed oil (Wesson), 3.0%. Vitamins A and D were administered orally twice each week.

The plan of the experiment is shown in table 1. While the rats were housed individually, feed and water consumption were measured by group. Five rats were used per group, and a control group receiving distilled water was used for each salt mixture. Five different salts were studied, each being added to

Table 1. Effect of Saline Drinking Waters on Rats

Group	Salt used	Concentration of salt in drinking water: Equivalents/l.	p.p.m.	Average daily gain of rats, gm.	Feed consumed/rat/day, gm.	Water consumed/rat/day, ml.
I	None	------	—	6.18	17.7	37.2
II	Sodium chloride	0.05	2,923	6.44	16.2	38.1
III	Sodium chloride	0.10	5,845	6.14	20.5	49.2
IV	Sodium chloride	0.15	8,768	6.37	19.0	48.0
V	Sodium chloride	0.20	11,690	6.03	18.6	39.0
VI	None	------	—	6.16	17.7	35.0
VII	Sodium sulfate	0.05	3,552	6.20	17.6	43.5
VIII	Sodium sulfate	0.10	7,103	6.06	17.9	42.2
IX	Sodium sulfate	0.15	10,655	5.88	17.7	42.2
X	Sodium sulfate	0.20	14,206	5.39	17.5	36.8
XI	None	------	—	6.18	16.8	36.2
XII	Magnesium chloride	0.05	2,381	6.07	17.8	37.8
XIII	Magnesium chloride	0.10	4,762	5.98	17.8	37.1
XIV	Magnesium chloride	0.15	7,143	5.58	15.8	36.0
XV	Magnesium chloride	0.20	9,524	4.93	16.2	41.2
XVI	None	------	—	6.02	16.7	34.4
XVII	Magnesium sulfate	0.05	3,010	6.16	17.4	39.4
XVIII	Magnesium sulfate	0.10	6,019	5.56	16.7	31.9
XIX	Magnesium sulfate	0.15	9,029	5.71	17.7	36.8
XX	Magnesium sulfate	0.20	12,038	5.60	16.0	34.6
XXI	None	------	—	6.00	16.5	39.6
XXII	Calcium chloride	0.05	2,775	6.04	17.6	33.1
XXIII	Calcium chloride	0.10	5,550	6.07	15.6	36.3
XXIV	Calcium chloride	0.15	8,325	6.10	17.8	27.4
XXV	Calcium chloride	0.20	11,100	5.84	15.0	27.8

the drinking water at four levels. Analytical grade salts were used in making up each of the waters.

Results and Discussion

Results of the work with rats are summarized in table 1. The various salts and concentrations used appeared to have no consistently great effect on feed consumption. Sodium chloride in the drinking water appeared to increase water intake, especially at the intermediate levels. Essentially the same was true for sodium sulfate. The magnesium salts had no particular effect on water consumption at any of the concentrations used. Calcium chloride reduced water intake at all concentrations.

The average daily gains for the rats were little affected by sodium chloride at any of the levels used. Sodium sulfate and the magnesium salts caused reduced growth rates at the higher levels. Calcium chloride had some slight effect in reducing daily gains at the highest level.

None of the animals died during the experiment, and while several showed symptoms of diarrhea on the sulfate salts, the symptoms were mild. Reduction in rate of gain seemed the most obvious effect of the saline waters.

These experiments indicated that the establishment of the exact level at which a salt or a mixture of salts becomes toxic or harmful would be difficult. Levels below 4,000 parts per million (p.p.m.) of a salt in the drinking supply appeared to have no adverse effect, while 10,000 p.p.m. usually did. On the basis of this work, and in view of some previous observations, the range between these two levels appeared to be the most logical for study with other animals.

CATTLE STUDIES

The salts commonly present at high concentrations in excessively saline waters of South Dakota are sodium sulfate, sodium chloride, and magnesium sulfate. Either sodium chloride or sodium sulfate will often account for over 75% of the total salts in these waters, while magnesium sulfate usually accounts for lesser amounts. As a rule magnesium sulfate is accompanied by high levels of sodium sulfate and some chlorides.

In view of this, the cattle studies were made with sodium chloride, with sodium sulfate, and with a mixture of magnesium sulfate with these two salts. The first trial, with sodium sulfate, included three levels of the salt, 4,000, 7,000 and 10,000 p.p.m. The second trial, involving the other salts, was limited to the two higher levels.

Methods

First trial. Twenty-four heifers in medium condition and weighing an average of about 670 pounds were started on the first trial on June 27, 1957. They were weighed without shrink and allotted into four uniform lots of six each.

All lots were fed alike. Alfalfa hay was limited to 6 pounds per head daily, and a concentrate mixture composed of 95% rolled shelled corn and 5% soybean meal was full fed.

Trace mineral salt and a mineral mixture (3 parts bone meal, 1 part limestone, and 1 part trace mineral salt) were offered free choice. The cattle were implanted with diethylstilbestrol after being on the experiment about 1 month.

Water from the Brookings water system was supplied to each lot in 350 gallon steel tanks. Sodium sulfate was dissolved in the water in these proportions: Lot 1, 10,000 p.p.m.; Lot 2, 7,000 p.p.m.; Lot 3, 4,000 p.p.m.; Lot 4, none (control). No adjustment period was used to allow the cattle to become accustomed to the water.

Second trial. Twenty steers and ten heifers of the Hereford and Angus breeds were used in this trial. They were in a fleshy condition and weighed an average of about 730 pounds when put on experiment June 3, 1958.

Rations fed were similar to those used in the first trial, except that the mineral mixture was composed of 2 parts bonemeal, 1 part limestone, and 1 part trace mineral salt. All animals were implanted with diethylstilbestrol at the beginning of the trial.

The cattle were weighed without shrink and allotted into five lots on the basis of weight, condition, and sex. Each lot was composed of four steers and two heifers.

The system of watering was similar to that used in the first trial. Salts were added to the water as follows: Lot 1, none (control); Lot 2, 7,000 p.p.m. sodium chloride; Lot 3, 10,000 p.p.m. sodium chloride; Lot 4, 7,000 p.p.m. mixed salts (sodium 955 p.p.m., sulfate 4,772 p.p.m., chloride 425 p.p.m., and magnesium 848 p.p.m.); Lot 5, 10,000 p.p.m. mixed salts (sodium 1,364 p.p.m., sulfate 6,817 p.p.m., chloride 607 p.p.m., and magnesium 1,212 p.p.m.)

Results and Discussion

First trial. Results of the first trial are summarized in table 2. Adding 10,000 p.p.m. of sodium sulfate to the water caused a marked reduction in feed consumption and rate of gain. The heifers in this lot (Lot 1) lost an average of 62 pounds per head during the first 2 weeks of the trial, and even after 56 days the average loss per head was 22 pounds (0.4 pounds per day).

Scours were rather severe in Lot 1, and two of the heifers showed pronounced additional symptoms indicating toxic effects. These symptoms were rapid and difficult respiration and incoordination. One of the heifers was removed from the experiment and given control water. Respiration and gait were normal on the following day and the animal was returned to experiment 8 days later. The other survived the experiment without being removed from the lot. A third heifer died after 55 days on experiment without showing the symptoms mentioned. A post mortem examination did not reveal the cause of death.

It was apparent after 56 days of the trial that 10,000 p.p.m. of sodium salfate made the water un-

Table 2. Effect of Different Concentrations of Sodium Sulfate in Water for Cattle (June 27-Sept. 19, 1957)

	10,000 p.p.m. sodium sulfate	None	7,000 p.p.m. sodium sulfate	4,000 p.p.m. sodium sulfate	Control water (Brookings)
Number in lot	6†	5†	6	6	6
Days	56	28	84	84	84
Av. initial weight, lb.	673.0	635.6	669.7	676.0	667.7
Av. daily gain, lb.	—.40	4.80	2.73	2.50	2.60
Av. daily ration consumed, lb.					
Alfalfa hay	3.2	5.9	5.8	5.9	5.8
Concentrate mixture	5.9	14.2	13.9	13.9	13.9
Mineral mixture	.050‡		.034	.092	.089
Trace mineral salt	.060‡		.062	.043	.117
Feed per 100 lb. gain, lb.					
Alfalfa hay	—	—	215	236	222
Concentrate mixture	—	—	511	557	536
Mineral mixture	—	—	1.23	3.67	3.44
Trace mineral salt	—	—	2.29	1.71	4.53
Av. daily water consumption, gal.					
June 27-Aug. 21	6.60		8.52	8.41	8.27
Aug. 22-Sept. 19		8.16	7.86	7.64	7.39
June 27-Sept. 19	7.07		8.30	8.15	7.98

*Lot 1, cattle changed to control water after 56 days.
†One heifer died. Gain made up to last weigh day before death counted in gain for the lot.
‡Values for entire experiment.

satisfactory, so at that time Lot 1 was offered control water. The experiment was continued for another 28 days. The return to normal appetite and appearance was rapid and the animals in this lot gained 4.8 pounds per day during this period (table 2).

The rates of gain for the lots receiving the water with 4,000 and 7,000 p.p.m. of added sodium sulfate were 2.50 and 2.73 pounds, respectively, as compared to 2.60 pounds for the control lot. The differences probably represent normal variation for the number of cattle used. Feed consumption also was not affected by these levels of sodium sulfate in the water.

All levels of sodium sulfate reduced free choice consumption of trace mineral salt. Consumption of the salt-bonemeal-limestone mineral mixture was reduced by the 7,000 and 10,000 p.p.m. levels.

Adding 4,000 or 7,000 p.p.m. of sodium sulfate to the water resulted in slight increases in the consumption of water. However, 10,000 p.p.m. of the salt caused a marked reduction in water consumption. The cattle offered the highly saline

water would consume only a small quantity at one drinking. They often licked the water with their tongues rather than drinking in a normal manner. Cattle in Lot 1 drank much more when returned to control water.

Second trial. Results of the second trial are presented in table 3. Since 7,000 p.p.m. of sodium sulfate in the water was satisfactory for cattle but 10,000 p.p.m. was toxic, these levels were used for testing the salts in this trial.

Neither 10,000 p.p.m. of sodium chloride nor the mixed salts produced the toxic effects or depression in feed consumption noted with a similar level of sodium sulfate in the first trial. However, this level of the salts resulted in a rather pronounced decrease in the rate of gain. Water with 7,000 p.p.m. sodium chloride or mixed salts did not affect rate of gain or feed consumption. This is in agreement with the results of the first trial. Apparently the toxic levels of salts in the water lie between 7,000 and 10,000 p.p.m., possibly at the physiological level (about 8,500 to 9,000 p.p.m.).

Effects of the added salts on mineral and salt consumption were variable. Both levels of added sodium chloride reduced consumption of the trace mineral salt and the salt-bonemeal-limestone mixture. The addition of mixed salts to the water, however, increased consumption of the mixture and had variable effects on salt consumption.

To see if the type of water had an effect on shrinkage, the cattle were shrunk for 24 hours at the end of the second trial. The differences shown in table 3 are not large considering the small number of animals used. Shrinkage was greatest for the control lot.

Four animals were removed from the experiment in this trial. One heifer was removed from Lot 1 after 88 days because of a prolapse of the rectum. One steer, previously treated with a sulfa drug for bloody scours, was removed from Lot 3 after 27 days because of an edematous condition. This condition may have resulted from urinary calculi, a matter that was not definitely established. One steer was removed from Lot 4 after 23 days because of urinary calculi, and one was removed from Lot 5 after 45 days with a condition diagnosed as edema of the glottis. In this latter case again the animal had been treated with a sulfa drug for bloody scours just prior to the appearance of the edema.

Cases of urinary calculi had been observed in the group of cattle from which those used in this experiment were selected, and it is doubtful that the water treatment was involved in causing this problem here. With reference to the edematous condition, however, the sulfa drug and the high level of salt may have been contributing factors.

An increased water consumption was noted for both levels of added sodium chloride. However, the addition of the mixed salts appeared to have no effect on water consumption, the small differences between the treatments and the control probably representing a normal varia-

Table 3. Effect of Different Concentrations of Sodium Chloride and Mixed Salts in Water for Cattle (June 3-Sept. 23, 1958—112 days)

	Control water (Brookings)	7,000 p.p.m. sodium chloride	10,000 p.p.m. sodium chloride	7,000 p.p.m. mixed salts	10,000 p.p.m. mixed salts
Lot number	1	2	3	4	5
Number in lot*	6	6	6	6	6
Av. initial weight, lb.	734.0	729.0	733.3	733.3	730.0
Av. daily gain, lb.†	2.41	2.36	1.96	2.28	1.80
Av. daily ration consumed, lb.					
Alfalfa hay	5.2	5.5	5.1	5.6	5.4
Concentrate mixture	14.0	14.5	14.1	14.3	13.0
Mineral mixture	.037	.028	.020	.044	.059
Trace mineral salt	.071	.053	.052	.087	.050
Feed per 100 lb. gain, lb.					
Alfalfa hay	214	231	261	248	301
Concentrate mixture	583	615	718	627	723
Mineral mixture	1.55	1.16	.99	1.95	3.28
Trace mineral salt	2.94	2.24	2.66	3.83	2.77
Av. daily water consumption, gal	7.69	8.96	9.94	7.38	7.78
Shrink, 24 hrs. off feed and water, %	6.72	5.75	5.46	5.79	6.46

*Numbers shown are for the initial number.
†Includes gain made up to last weigh day for those removed from lot.

tion for groups of such small numbers of animals.

SWINE STUDIES

It is generally assumed that swine are more susceptible to injury from saline waters than are cattle. Therefore, in undertaking a study with growing pigs, it was decided that lower concentrations of salts should be used. In addition, facilities were such that the work had to be limited to one type of saline water, so it was decided that a mixture of salts should be used. This mixture included sodium chloride, magnesium sulfate, and sodium sulfate, added at a ratio similar to that found often in natural waters.

Methods

Sixty weanling pigs averaging approximately 37 pounds were used in this trial conducted in concrete drylot from June 10 to September 8, 1958. The pigs were divided into four lots of 15 pigs each on the basis of ancestry, weight, and sex. All lots of pigs were self-fed the same basal ration. This ration consisted of 84 parts corn, 10 parts soybean meal, 5 parts tankage, 0.5 part steamed bonemeal, 0.5 part trace mineral salt, and B-vitamin and antibiotic supplement. When the pigs weighed about 110 pounds the corn was increased to 91 parts and the soybean meal and tankage were reduced to 5 and 2.5 parts, respectively.

Each of the four lots of pigs received a different water, as follows: Lot 1, Brookings water; Lot 2, Brookings water plus 2,100 p.p.m. of added salt mixture; Lot 3, Brookings water plus 4,200 p.p.m. of added salt mixture; and Lot 4, Brookings water plus 6,300 p.p.m. of added salt mixture. The salt mixture was composed of 1 part of sodium chloride and 3½ parts each of sodium sulfate and magnesium sulfate. The pigs were placed on those waters directly, no attempt being made to accustom them to each gradually.

Results and Discussion

The results summarized in table 4 show that there were no harmful effects from water containing up to 6,300 p.p.m. of the salt mixture (about 7,000 p.p.m. total salts when the composition of the Brookings water is considered) on growing-finishing pigs. In fact, the average daily gain, feed consumption, and feed efficiency were better for all three lots given water with added salts than for the control lot (water with no added salts).

Increasing the salt content of the water did increase water consumption. It was also noted that the pigs receiving the salt in their water scoured during the early weeks of this trial. This scouring was more apparent in Lot 4 than in the other lots. However, it apparently had no harmful effect on the gains or general condition of the pigs.

The increased weight of the pigs getting water with added salt was not due to an increase in fill. After the final weigh period, all pigs were withheld from feed and water for 16 hours and reweighed. The average shrink per pig was 10.1, 8.9, 9.3, and 9.7 pounds for Lots 1, 2, 3, and 4, respectively. It was not determined in this trial whether there was a greater water retention in the tissues of the pigs receiving the water with added salt.

POULTRY STUDIES

Only limited work with poultry has been completed, but studies are being continued and results will be reported more completely later. Therefore only a summary of findings to date is reported here.

Laying hens in cages have been kept on waters containing 4,000, 7,000, and 10,000 p.p.m. of added sodium chloride and on water with no added salt. At all levels of added salt, watery droppings have been observed. The severity of this condition appears to correlate with salt content of the water. It has also been found that the added salt increases water consumption, the greater the salt content, the greater the water consumption.

Except for watery droppings, the 4,000 and 7,000 p.p.m. of added sodium chloride did not appear to harm the birds. Egg production and body weight data were as good for these two salt levels as for the control hens. At the 10,000 p.p.m. level, however, egg production and body weight were adversely affected.

From the study discussed here, it appears that poultry may be very much like other animals with respect to their tolerance of saline waters. Studies now in progress

Table 4. Saline Waters and Swine Performance

	Lot 1 no added salts	Lot 2 2,100 p.p.m. added salts	Lot 3 4,200 p.p.m. added salts	Lot 4 6,300 p.p.m. added salts
Number of pigs	15	15	15	15
Av. initial weight, lbs.	37.4	37.4	37.2	37.2
Av. final weight, lbs.	164.6	172.8	180.1	174.8
Av. daily gain, lbs.	1.41	1.51	1.59	1.53
Feed/pig/day, lbs.	5.35	5.47	5.54	5.59
Feed/pound of gain, lbs.	3.79	3.62	3.47	3.66
Water consumption (gal./pig/day)	1.06	1.30	1.42	1.48

should clarify this matter, especially those studies dealing with growing poultry.

SUMMARY

The purpose of the work described here was to determine the effects of saline waters on livestock and the level at which salinity makes a water unsuitable for livestock. Rats, cattle, swine, and poultry were used in the various studies.

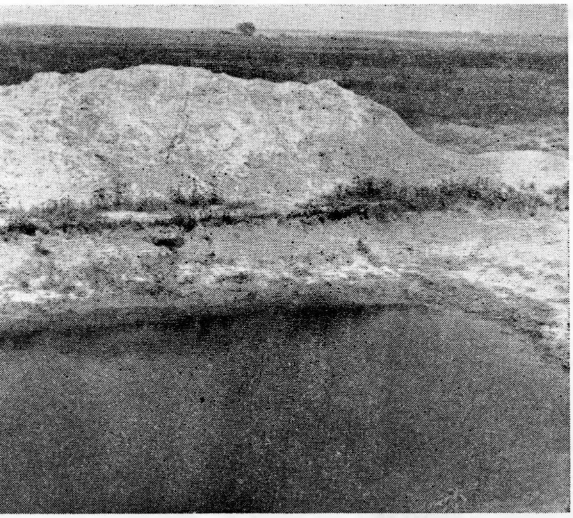
Preliminary experiments were made with rats, using five different salts, each at four levels. These experiments indicated some differences with regard to effects of the various salts, but it appeared that water with a salinity of about 4,000 p.p.m. had no toxic effect, while water with a salinity of around 10,000 p.p.m. usually did, regardless of the type of salt.

Trials with fattening cattle included the study of waters containing added sodium sulfate, sodium chloride, or a salt mixture containing sodium chloride, sodium sulfate, and magnesium sulfate. Here it was found that in each case a level of 7,000 p.p.m. caused no reduction in weight gain or feed consumption, and the animals appeared normal. At a level of 10,000 p.p.m., reduced gains were found with all of the waters, and in some animals on sodium sulfate water, severe symptoms of toxicity were observed.

Three different levels of an added mixture of salts were used for swine. The highest level gave a total salts content of about 7,000 p.p.m. Other than some slight scouring in the pigs on the higher levels early in the experiment, no ill effects were observed. Increasing salt content resulted in increased water intake, but rate of gain and feed efficiency were not adversely affected.

In laying hens, added sodium chloride at a level as low as 4,000 p.p.m. caused watery droppings. At 7,000 p.p.m. no additional adverse effects were noted, while at 10,000 p.p.m. egg production and body weight were both adversely affected.

In general, the results of these studies indicate that toxic effects can be expected from waters containing 10,000 p.p.m. of soluble salts, regardless of the type of salts.



Note salt deposits around the edge of this dugout.

Waters with 7,000 p.p.m. of soluble salts apparently cause little, if any, real damage to livestock, but because of taste qualities and laxative effects from certain salts these waters cannot be considered as entirely satisfactory for livestock. Incorporating a reasonable margin of safety to provide for exceptional conditions, it appears that a water with over 7,000 p.p.m. of soluble salts should be classed as unsatisfactory for livestock.

Based on these studies and on observations made during the past several years, the following criteria are suggested for relating salinity to the quality of a livestock water:

Total Salts Content of Water* (p.p.m.)	Quality
0-999	Excellent
1,000-3,999	Good
4,000-6,999	Satisfactory
7,000 and over	Unsatisfactory

*Values for conductivity in micromhos per cm. at 25° C. may be used here if total salts content is not known.

Other factors are, of course, important in determining the quality of livestock waters. These include such things as whether or not the water is excessively turbid, stagnant, or insanitary.

In addition, excessive nitrates, alkalinity (not to be confused with salinity), or unusual poisons make livestock waters unsatisfactory. Occasionally iron content is so high as to make a water objectionable because of its taste. Therefore, these factors must be considered in addition to salinity in evaluating a livestock water. Lack of experimental work prevents publication of standards relating to these factors at this time.

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