OKLAHOMA
AGRICULTURAL AND MECHANICAL COLLEGE
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C. P. BLACKWELL, Director

Stillwater, Oklahoma

The Effect of Saline and Alkaline Waters on Domestic Animals

V. G. HELLER
DEPARTMENT OF AGRICULTURAL CHEMISTRY RESEARCH
OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE

Cow No. 2, a Holstein, with her calf, after drinking 1.5 percent sodium chloride water solution for two months

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THE EFFECT OF SALINE AND ALKALINE WATERS ON DOMESTIC ANIMALS

V. G. HELLER

INTRODUCTION

Because water is so widely distributed, few stop to consider its importance or the effects of an inadequate or impure supply. The growth of nations, the location of great cities, and the success of their peoples can be closely connected with the character and quantity of the water supply. The utilization of water may be classified as follows: 1, for drinking; 2, for irrigation; 3, for industrial uses (in boilers, as solvent, for cleanser, in hydraulics, etc.).

The scope of this discussion will be confined to the first division, namely, to waters used for drinking purposes and the occurrence of water in animal life. It is the principal constitutent of living tissue, as two-thirds of the body of the average man or animal consists of this compound, 75 to 90 percent of the active tissue and 40 percent of the bones being water. It comprises the greater part of the vegetables, forages, milk, and meat necessary for sustenance.

Despite its great importance, water is a very simple compound made by the chemical union of two common gasses in the proportion of two volumes of hydrogen to one volume of oxygen. However, pure water is a rare compound. Even water that has been carefully distilled may contain other constituents, because it is such an excellent solvent for gasses, liquids and solids that it is practically impossible to separate it entirely from all contaminations. Distilled water does leave behind most of its dissolved solids; but the liquids and gasses very often pass through the still along with the steam, and it is almost impossible to separate them.

Of the naturally occurring waters, falling rains are as pure as can be found, but an examination shows that even rain water has dissolved within it many gasses such as nitrogen, oxygen, and carbon dioxide. Likewise, small particles of dust, bacteria, and traces of many soluble salts are to be found. Such impurities are increased by air pollution near cities. The surface of the earth is composed of various compounds—salts, minerals, strata of rock and often beds of old seas where deposits of soluble salts are found. The rain, trickling through the soil and crevices in the rock, dissolves some minerals, and in places where soluble salts abound it may become saturated. Such waters are sometimes called mineral spring or mineral well waters and are recommended for medicinal purposes due to the salt content.

It has been the custom to call a water containing only a small amount of dissolved solids a fresh or "soft" water. In regions where the rock formation permits the water to dissolve salts of calcium, magesium, iron, and certain other less common salts, the water is called "hard" water. Such waters are not satisfactory for boiler use, due to the scale left upon the interior of the boiler; but they are often preferred for drinking purposes because of the palatable flavor produced by traces of dissolved salts.

There are other waters that do not belong to either of these groups, but which contain dissolved within them large amounts of sodium chloride (table salt) and other closely related salts. There are still others which contain alkalies such as sodium carbonate, sodium hydrogen carbonate, sodium hydroxide, and related compounds. These waters are referred to as saline and alkaline waters and are of primary concern in this investigation. One of the best illustrations of such a water is that found in all our oceans and in deep wells that penetrate submerged lakes thought to have been at one time connected with the sea. A gallon of such a water may contain 2,110 grains of dissolved salts (usually consisting principally of common table salt); or in other words about 3.6 percent of the weight of the water is composed of the salts present; or, putting it in terms of the chemist, the water contains approximately 36,000 parts per million of dissolved solids.

Due to peculiar changes that have taken place in prehistoric times, certain areas of the earth have been raised above the sea level and in some cases enormous bodies of sea water are supposed to have evaporated away leaving the salt content in the land. In such places, it is not surprising that the water from the soil is quite salty or alkaline. Fortunately the greater portion of the earth does not exhibit such conditions and its inhabitants are not acquainted with the serious problems presented by such waters. However, practically every country has extensive areas so affected. The southwestern part of the United States is typical of such a region. In certain respects the conditions are not so bad in Oklahoma as in other sections, but they are as variable as can be found in any equal area.

The waters of the eastern portion of Oklahoma might be classified as slightly hard, coming from limestone veins. These are excellent in taste and composition and sparklingly clear. In other sections of the State are vast salt plains, which give rise to the opinion that this was at one time a sea basin. In dry weather the salt forms on the surface of the soil. Save for certain salt tolerant bushes, vegetation is absent. Wells and streams of this section become so saline that oftentimes aquatic life is destroyed and animals which drink the water are injured.

In the western section of the State, alkalies occasionally occur in the form of sodium bicarbonates or carbonates. In other localities, "gyp" or calcium sulphate beds are found. The rain water falling on this land seeps through the rock layers and becomes saturated with this compound, appearing again in springs or wells and giving them their characteristic brackish taste. Epsom salts or magnesium sulfate is a common constituent occurring quite generally in many wells. There are large springs and mineral wells in the State containing considerable quantities of sodium chloride, sodium or potassium carbonate, often sodium, calcium or magnesium sulfates, and smaller amounts of other materials said to have medicinal properties.

Probably the greatest problem is the deep well. Often it is necessary to depend upon small artificial lakes to impound rain water because of the salinity of deep waters. Apparently there are immense subterranean lakes containing waters resembling in many respects the ocean waters. Waters of this nature are emulsified with the crude oil and cause much trouble in the oil fields. The salts in these waters are composed largely of sodium, calcium and magnesium chlorides and smaller amounts of other salts. Such oil well brines may contain 200,000 parts per million, or 20 percent, dissolved salts. The disposal of these brines is a problem to the oil industry. If pumped into a small stream, the water may become dangerous to plant and animal life. If it is poured upon the land to evaporate, vegetation is injured and the water seeps into shallow water veins. If it is pumped back into dry oil wells there is danger that it may seep into oil veins and destroy producing wells. In most oil and gas sands the porous rock soon fills with silt so that it is impossible to put the salt water back into the well even when high pressure is used. This may be due in part to the rock pressure or settling of the earth as well as to clogging of the pores of the rock.

The wide distribution of such waters, the frequent inquiries in regard to their effects upon plant and animal life, and the apparent lack of definite information in the scientific literature have impelled an investigation of this problem.

REVIEW OF PREVIOUS STUDIES

Saline waters are common in Australia. Several workers there have investigated salt waters said to have been responsible for the death or sickness of domestic animals.

Ramsey[11] analyzed many of these waters and in each case questioned the user as to what effect they had on livestock. From the users' answers a permissible tolerance was established for horses, cattle and sheep. It must be remembered, however, that these results are based largely upon suppositions, and such information is always subject to biased viewpoints. The writer has frequently received absolutely contradictory answers to such inquiries. Ramsey calls attention to such variations in his data.

In 1924 Scott,[13] a veterinarian, reported a study he had made of a salt water malady in cattle. A stream polluted with salt water had supposedly killed a number of cattle. He secured some of this water and used it as a sole source of drinking supply for cattle for 14 days and recorded his observations in detail. Unfortunately, he fails to give a chemical analysis of the water he used, and it is impossible to state with what salt combinations and concentrations he was dealing. The single analysis of the chloride content of the water calculated in terms of sodium chloride might be very misleading as to the real cause of trouble. His description of conditions observed has not been substantiated in many of our carefully controlled studies, and it is probable that he was dealing with factors other than sodium chloride toxicity.

Brunnich[2] recorded the analyses of many saline waters of Queensland and commented on their use for irrigating and drinking purposes, based upon his observations and the reports of others. The work is of interest from the standpoint of comparing the nature of the mineral waters of the two continents, as it is noticeable that a great many of the Australian waters contain a higher percentage of magnesium sulfate and sodium sulfate than most of the waters of the southwestern part of the United States However, it furnishes no definite data to solve the problems of salt toxicity.

Clough[4] described the death of chickens which had accidentally consumed considerable quantities of salt in their feed. His report shows quite definitely that a large amount of salt will kill a bird, but the fact that it was eaten dry presents an entirely different problem than that involved in continuous consumption of smaller amounts in drinking water.

Mitchell, Card and Carman[9] and Quigley and Waite[10] report similar observations in this country.

Legg[8] reported the reactions in sheep presumably injured by accidentally consuming waters thought to have been contaminated with salt waste. The report gives no analysis of the waters and no statement as to the conditions, the article, as stated by the author, being merely a record of injuries thought to have been produced by salt.

This Station in 1930[6] and again in 1932[7] reported the effects of saline and alkaline waters of known concentrations upon the growth, reproduction and general well being of rats, covering three generations. This report differed from any previous investigation in that studies were made of synthetic solutions and under absolutely controlled conditions over long periods of time, so that resulting effects could be definitely correlated with known causes.

EXPERIMENTS AND RESULTS

Effect of Saline and Alkaline Waters Upon Rats

As previously stated, rats were first used in this investigation because they are commonly accepted laboratory control animals. Their growth curves, food consumption, and general reactions to feeding trials are definitely known. In addition, they can be kept in confinement so that they do not secure other foods or waters, a requirement more difficult to control with larger animals kept in outdoor pens. Further, their growth and reproduction period is so short that one can make observations through a series of generations that would take many years with large animals.

In all of these tests the animals were confined in metal cages and given a well balanced ration known to be satisfactory for normal growth. The water was given in inverted bottles fitted with syphons. In this way it was possible to measure the food and water intake accurately day by day. The solutions were made by dissolving definite amounts of pure salts in pure distilled water. This prevented the possibility of secondary effect of small contaminations; and it was possible to record not only the effect of each salt but also of various concentrations. Having determined the effect of a single salt, it was possible to add other salts to the solution and determine whether or not antagonistic ion action was probable. The details of procedure and the accumulated data having been published elsewhere,[7] only a summary of the results is recorded in Table 1.

TABLE 1.—Results Obtained by Use of Saline Waters as a Sole Source of Drinking Supply for Rats

Salt	Per-cent by wt.	Males	Fe-males	Lit-ters	Young born	Young lived	Young died	Remarks
$NaCl$ Sodium Chloride	0.5	2	3	3	24	20	4	Growth normal.
	1.0	1	1	1	7	4	3	Growth normal.
	1.5	3	5	5	39	31	8	Growth subnormal. Some die.
	2.0	2	3	3	20	17	3	Young die.
	2.2	1	2	0	0	0	0	Old and young die.
	2.5	4	6	0	0	0	0	Old and young die.
	3.0	2	2	0	0	0	0	Sudden loss in wt., diarrhea, rough hair, and death.
	3.5	2	2	0	0	0	0	Young and mature die soon.
	4.5	4	2	0	0	0	0	Die at once.
$NaCl+KCl$ Sodium Chloride and Potassium Chloride	1.5 0.7	2	3	3	39	0	39	Young die within 15 days.
	1.7 0.6	2	2	0	0	0	0	Old ones die.
	2.5 1.0	2	4	0	0	0	0	Old and young die.
	3.0 1.5	2	4	0	0	0	0	All die within a week.
$NaCl+CaCl_2$ Sodium Chloride and Calcium Chloride	1.5 0.7	5	4	1	7	0	7	Hair thin and rough. No gain.
	3.0 1.5	4	4	0	0	0	0	All die at once.
$CaCl_2$ Calcium Chloride	1.0	2	2	2	13	10	3	General condition good.
	1.5	3	6	7	77	62	15	Growth satisfactory. Condition good.
	2.0	1	2	5	30	6	24	Interferes with lactation.
	2.5	1	1	0	0	0	0	Old ones die.
$MgSO_4$ Magnesium Sulfate	0.5	2	2	2	10	10	0	Growth and reproduction.
	1.0	1	3	6	51	24	27	Young poor; old emaciated.
	1.5	3	3	3	20	13	7	Growth subnormal; diarrhea, rough coat.
$MgCl_2$ Magnesium Chloride	1.0	2	4	2	15	1	14	Condition of old not normal.
	1.5	1	2	0	0	0	0	Growth below normal.
$MgCl_2+CaCl_2$ Magnesium Chloride and Calcium Chloride	1.0 0.5	2	2	1	7	0	7	Growth of old normal. Lactation poor.

TABLE 1.—(Continued)

Salt	Per-cent by wt.	Males	Fe-males	Lit-ters	Young born	Young lived	Young died	Remarks
$Mg(C_2H_3O_2)_2$ Magnesium Acetate	1.5	2	2	2	17	8	9	Growth satisfactory. Reproduction.
Na_2CO_3 Sodium Carbonate	1.0	3	7	7	45	31	24	Growth of offspring unsatisfactory.
	1.9	1	7	2	19	0	19	Young die; old rough coated, red eyes, diarrhea.
$NaHCO_3$ Sodium Hydrogen Carbonate	1.5	2	4	7	55	48	7	Old somewhat undersize. Growth of offspring impeded.
	2.0	1	2	2	14	7	7	Growth and appearance unsatisfactory
NaOH Sodium Hydroxide	0.5	2	4	0	0	0	0	Practically normal growth.
	1.0	3	4	0	0	0	0	Little growth, animals dirty, very nervous, diarrhea, sore eyes.
$Ca(OH)_2$ Calcium Hydroxide	sat.	4	4	4	30	19	11	Some interference with growth during lactation. 3 generations produce.
$CaSO_4$ Calcium Sulfate	sat.	3	8	7	33	28	5	Satisfactory growth.
Na_2SO_3 Sodium Sulfate	1.5	1	2	1	11	6	5	Appearance of adults satisfactory.
NaF Sodium Flouride	1.0	1	2	0	0	0	0	Growth poor. Animals emaciated.
KI Potassium Iodide	1.0	1	2	0	0	0	0	Growth fair. No reproduction.

The data in Table 1 may be briefly summarized as follows:

1. Waters containing large amounts of salts in solution are deleterious for drinking purposes.
2. The effect produced seems to be more osmotic in reaction than due to any specific ion.
3. From 1.5 to 1.7 percent seems to be the maximum amount of soluble salts that can be used with safety.
4. Animals seem much less susceptible to salt than plants, and antagonistic action of ions is lacking or is a secondary factor.
5. Chloride salts are less injurious than sulfates, and organic salts are less injurious than inorganic.

6. Alkalies are more deleterious than normal salts; evidently the osmotic result is coupled to a harmful effect of the changed alkalinity.
7. An interference in lactation and reproduction is noticeable even before the level producing stunted growth or death is reached.

Effect of Saline and Alkaline Waters Upon Laying Hens

Rhode Island Red hens one year old secured from the flock of the Poultry Department of this Station were distributed in groups of 8 through a series of pens in order to be as comparable, pen for pen, as possible. The A. & M. Laying Mash* was fed to all chickens. Pen No. 1 was designated as the control lot and received city tap water, which is low in mineral content. Other lots received waters containing salts as designated in Table 2, covering a ten-week period.

TABLE 2.—Effect of Various Concentrations of Salt Waters Upon Laying Hens

Pen No.	Salt concentration in water	AVERAGE WT. Beginning	AVERAGE WT. End	Gain or loss	Wt. 3 wks. later on tap water	Gain or loss	Remarks
		lbs.	lbs.	lbs.	lbs.		
1	City water	3.7	3.9	+.2	4.2	+.3	Normal
2	1% NaCl	2.9	3.3	+.4	3.6	+.3	Normal
3	1.5% NaCl	3.15	3.2	+.05	3.9	+.7	
4	2% NaCl	3.0	2.5	−.5	3.3	+.8	1 died
5	1.5% $CaCl_2$	4.8	2.9	−.9			Poor
6	2% $CaCl_2$	4.05	2.4	−.65			Bad; rough
7	1% $MgSO_4$	3.1	2.8	−.3			
8	1.5% $MgSO_4$	3.9	3.3	−.6			Fair

*Composition of this mash may be obtained from the Poultry Department of this Institution.

An examination of the figures in Table 2 indicates (1) that waters containing sodium chloride do not interfere with normal growth and maintenance until the concentration has reached 1.5 percent or more, (2) that calcium chloride is not as well tolerated as sodium chloride, and (3) that magnesium sulfate is tolerated surprisingly well, even up to 1.5 percent, after a first period of adjustment.

Effect upon egg production. Young White Leghorns from the College flock were divided into lots of 25 each and fed the A. & M. Laying Mash. All were in average production. Table 3 shows that when the hens were first placed upon salt water, egg production ceased and a period of time (depending on the concentration of the solution) elapsed before laying was resumed.

TABLE 3.—Effect of Salt Waters on Egg Production

Type of Water	EGGS PRODUCED PER HEN PER WEEK WHILE ON SALT WATER 1st	2nd	3rd	4th	5th	6th	7th	8th
City H_2O	25	45	60	72	84	72	70	84
1% NaCl	0	0	12	18	36	42	72	108
1.5% NaCl	0	0	0	0	6	18	36	90
2% NaCl	0	0	0	6	12	12	24	48

It must be noted that this test was run in the coldest part of the year starting December 27 and continuing until March. There was, therefore, a natural increase in egg production of all groups due to the season of the year, but it should be repeated that all the groups were laying at the beginning and that a period of readjustment was passed through before they were again normal. Two percent sodium chloride was clearly too saline, because the hens' feathers became rough, they lost weight, and some died. Egg production was not normal for this group the remainder of the season, even after being returned to city water.

Effect of Saline and Alkaline Waters Upon Sheep

The sheep used in these tests were chosen from a carload lot which had been used for feeding experiments in the Animal Husbandry Department, classified as grade Rambouillet, originally purchased from the ranges of southwestern Texas. They had become accustomed to their surroundings and were well adapted to the dry lot feeding tests. They were divided into groups of five each and were fed mixed grain and prairie hay. The tests were conducted in the coldest period of mid-winter and repeated in the hot summertime in order to remove all doubts in regard to the effect of larger intake of water. Daily observations and daily weights were recorded for each animal throughout the trials—a period of six weeks. In order to save space these data have been averaged and are presented in Table 4.

TABLE 4.—Effect of Various Concentrations of Salt Waters Upon Sheep

WINTER TESTS

Type of water	Beginning weight	Final weight	Change in weight	Remarks
	lbs.	lbs.	lbs.	
City water	58	66	+8	Normal
2% NaCl	57	58	+1	Maintained
2.5% NaCl	57	57	0	Off feed at times
City water*	62	62.3	+.3	
2% $CaCl_2$*	65	58	−7	
2.5% $CaCl_2$*	65	59	−6	

*The animals on $CaCl_2$ experiments were run at a later date than those on NaCl, and consequently a new control lot was run with them. The severity of the weather is shown by the fact that the controls did not gain as well as the NaCl controls. This fact should be kept in mind in making any comparisons between the two salts.

SUMMER TESTS

Type of water	Beginning weight	Final weight	Change in weight	Av. water consumption	Remarks
	lbs.	lbs.	lbs.	gal. per day	
City water	102	98.5	−3.5	0.6	
2% NaCl	100	93.0	−7.0	1.17	1 died on a very hot day.
1.5% $MgSO_4$	110	104.0	−6.0	0.5	
2% $MgSO_4$	106	101.0	−5.0	.6	

As noted in the table, one sheep died on a very hot day (110°F.). In an attempt to see if the death was due to the salt water and also to determine what effect it had on the body, Dr. Lewis Moe, college veterinarian, was asked to make an autopsy. His report was as follows:

1. Sheep had eaten little and drank but 4 lbs. of water per day for some time.
2. Staggered and threw head back at 9:00 p. m.
3. Removed from pen and given tap water at 10:00 p. m. Relieved somewhat.
4. Died at 4:00 a. m.
5. Autopsy showed intestines empty. Intestines not red but indications of chronic enteritis were noticeable. Lymph glands normal; spleen normal; kidneys small; hyperaemia in right kidney; liver small and degenerated; lungs showed marked edemia; heart soft and flabby; mucous membrane of mouth and nose cyonatic.

Sheep are evidently more tolerant of salt waters than any other animal. However, they received no salt in their feed and did not touch the salt supplied separately.

It has been observed in all our tests that animals accustomed to drinking fresh water will refuse to use salt water if they have access to salt regularly. It usually takes a full week after changing to a saline solution before they will resume normal consumption of water. It is often stated that animals will choose to drink salt waters that are injurious to them even though good water is accessible. In order to test this theory, the sheep were offered both pure water and saline waters at the end of the above experiment. The group which had been receiving pure water drank 0.6+ gallon per sheep per day and little of the 1.5 percent salt solution. The group which had been drinking 2 percent salt solution drank 1.5 gallons of pure water per sheep per day and none of the salt water. This test has been repeated frequently on various groups of animals and in no case has it been found that they prefer salt waters.

Effect of Saline and Alkaline Waters Upon Hogs

In experimenting with hogs two sizes were used, both in hot and cold weather. The smaller pigs, six in number, weighed in the neighborhood of 50 pounds each, and a similar number of larger ones weighed somewhat over 100 pounds each. They were divided into groups as similar as possible and placed in paved pens to which they were accustomed. The feed was a mixture of grains supplemented with animal proteins, such as is used for young hogs by the Animal Husbandry Department of this Institution. The various solutions were made up in large lots and measured amounts placed in covered waterers to prevent waste. The amounts of feed and water consumed were recorded for each hog daily for a period of six weeks. The weights at two week intervals, amounts of water consumed and feed eaten are recorded in Table 5A.

Within 30 days the small pigs consuming 1.5 percent NaCl (sodium chloride) had died and the larger ones were somewhat stiff when walking. At this time they became very restless and nervous and refused to drink sufficient amounts of the salt water. The food consumption was greatly decreased, and the general appearance of the animals was not good. They were removed from the salt water and given pure water and were practically normal in 10 days.

An autopsy of those that died presented a picture similar to the one described for the sheep. The intestinal tract had become somewhat reddened. It is thought that there was an interference in digestion and a lower food consumption. Possibly the deaths might have been caused by toxins from the intestinal tract due to impaired digestion and absorption.

The tests were repeated during the hot weather of the following summer in the same manner except that no attempt was made to keep the feed of

TABLE 5A.—Effect of Various Concentrations of Salt Water Upon Hogs. Winter.

(Average per hog per day)

Date	CITY WATER				1.0% NaCl				1.5% NaCl			
	AV. WEIGHT				AV. WEIGHT				AV. WEIGHT			
	Large	Small	Feed	Water	Large	Small	Feed	Water	Large	Small	Feed	Water
	lb.	lb.	lb.	gal.	lb.	lb.	lb.	gal.	lb.	lb.	lb.	gal.
11-18-32	98	47	5	2	106	51	5	2	140	46	5	2
12- 1-32	107	54	5	2	112	54	5	2	122	40	2.5	2
12-15-32	118	59	5	2	130	60	5	3	139	Died	2.5	2
1- 1-33	135	70	5	3	148	68	5	5	142		2.5	1
Av. Gain	37	23			42	17			2			

the various lots equal and only one size of hog was used to a group of three hogs each. It will be noted that the feed consumption as well as the water intake decreased as the salt content of the water was increased. This reaction has been noticed with so many lots of various types of animals that there is much evidence to indicate that much of the so-called salt injury is not a direct injury but a condition of partial starvation due to an inadequate intake of feed and water to supply the maintenance requirement. A slight leg stiffness was encountered again in the group consuming 1.5 percent salt. This stiffness soon disappeared and the only difficulty noted during the five-week test period was the lack of normal growth. Blood tests failed to reveal any abnormal symptoms. Even the salt group soon returned to normal when returned to city water, their growth exceeding the other lots during the next month, which further indicates that no injury was done save the self-starvation.

TABLE 5B.—Effect of Various Concentrations of Salt Water Upon Hogs. Summer.

(Average per hog per day)

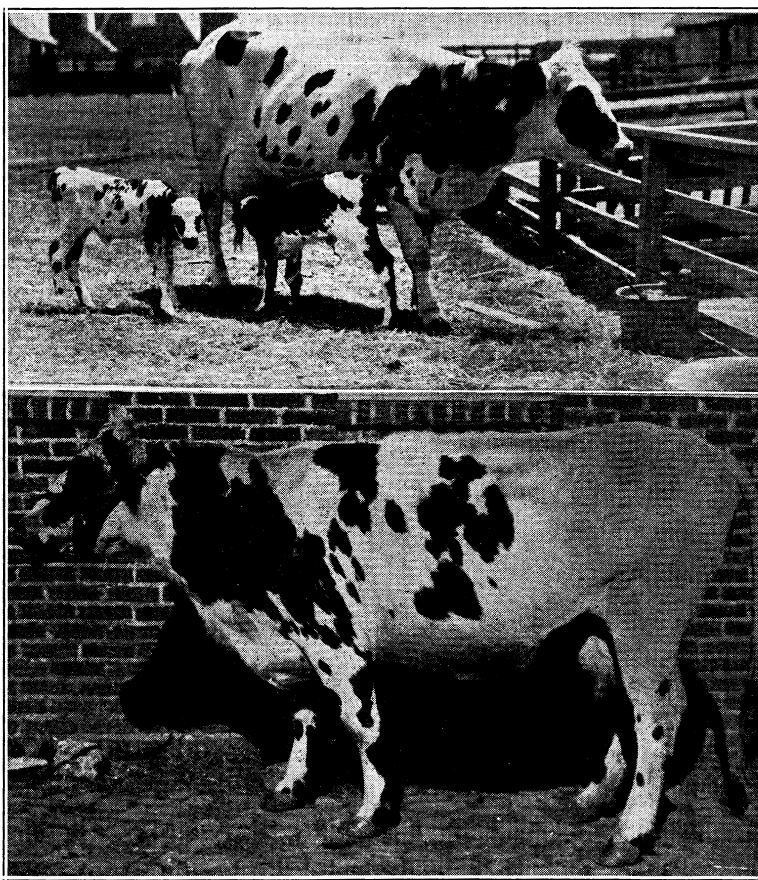
	CITY WATER			1.0% NaCl			1.5% NaCl		
Date	Av. weight	Feed	Water	Av. weight	Feed	Water	Av. weight	Feed	Water
	lbs.	lbs.	gal.	lbs.	lbs.	gal.	lbs.	lbs.	gal.
8-28-33	72	2.25	1.0	70	1.75	0.75	70	1.15	1.00
9- 1-33	80	2.25	1.0	72	1.85	0.75	67	1.55	1.00
9- 5-33	86	2.25	1.1	80	1.60	0.75	68	0.60	0.85
9-11-33	92	2.75	1.5	80	2.50	0.75	67	0.65	1.00
9-18-33	103	2.75	1.1	100	2.75	0.75	69	1.00	1.00
9-29-33	116	3.00	1.5	108	3.00	1.50	71	1.00	.90
Av. Gain	44			38			1		

Hogs are undoubtedly more susceptible to the salt injury than other domestic animals, this being especially noticeable during the winter months. The 1 percent NaCl solution seems not to be particularly injurious after the animals have become accustomed to the taste.

Effect of Saline and Alkaline Waters Upon Cattle

The experiments with cattle have been similar to those with small animals, but have proven to be very interesting to practical farmers and ranch men as there has been so much alleged damage to livestock on the ranges. In summer, small streams often run only part time or in small volumes; as a result there is less water to dilute the salt contaminations and the water may become dangerous to animals. Ranchmen do not realize that the water is changing until the damage is done. In many cases salt water escaping from oil wells finds its way into streams whose flow is too small to make sufficient dilution. Much damage undoubtedly has resulted. There is much conflicting evidence in regard to this matter, however, and many almost mythical tales are told of sudden deaths which are, as a rule, not possible to verify. The writer has attempted to investigate many such rumors, but usually they seem to be founded upon hearsay or the deaths are traceable to other causes. However, certain damage has been found to occur where cattle do not have access to other drinking supplies and the water becomes too saline for safe use. Where ranges adjacent to such streams are used, fresh water should be constantly supplied from other sources and regular examination made of the creek flow during dry seasons. Repeated experiments at this Station fail to show that cattle well fed and salted will drink water that is injurious if better water is available, although this statement has frequently been made by laymen.

The cattle used in these tests were both grade and purebred animals of various breeds and ages—Jersey, Guernsey, Holstein, Shorthorn, and cross-bred—all secured from the College. The greater number were milk cows as we were especially interested in the effect on milk production and abortion, since it has been reported that cattle receiving salt water aborted. The reactions of various animals were usually similar, so that typical animals will be discussed and the data for those animals will be shown. In all cases, the animals were confined to stalls or dry paved yards the greater portion of the time to make certain that no water was obtained except that

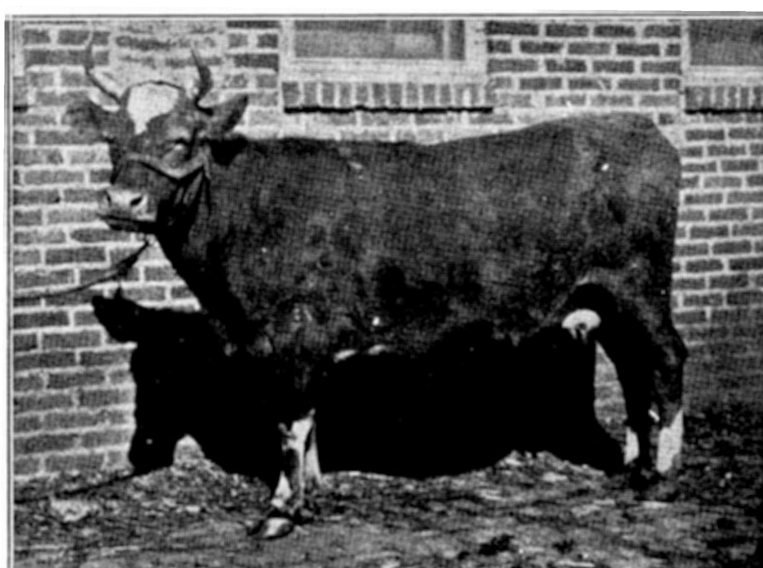


(Below) COW NO. 3, Holstein, at the beginnng of the salt water tests with 1.5 percent sodium chloride solution.
(Above) COW NO. 3, the same Holstein, and her twin calves, after having been on 1.5 salt water solution for 13 weeks.

contained in the dry feed. A mixed cereal ration known as the A. & M. Dairy Ration,* used as feed for the College herd, was fed throughout the tests. Alfalfa and wild prairie hay were fed **ad libitum.** In the late summer tests the cattle were permitted a few hours exercise in a grass pasture.

Cow No. 35 was a Grade Shorthorn. On January 9 she was started on water containing 15,000 parts per million of salt (1.5 percent). She refused to drink water until January 17, when she consumed 2 quarts. During this time she ate little and irregularly. The action of the rumin was slight most of the time. The water intake was increased and by January 23 she was drinking 3 gallons per day. All the grain and most of the hay supplied were consumed. She was continued on the test until February 20. During the latter month she reacted like a normal animal. The first two weeks she lost 40 pounds in weight. During the last month this weight was regained, and at the conclusion of the experiment she was sold on the open market.

Cow No. 70 was a Grade Jersey. On January 8 she was started on 20,000 parts per million of sodium chloride (2.0 percent). She refused to drink until January 17, when she drank 3 quarts. During this time food consumption was cut down and she lost weight. During the remainder of the month she never drank more than 1⅛ gallons per day. She ate irregularly and never much. Rumination was never normal. The feces became dry and slight. There was a constant loss of weight and the animal assumed an emaciated appearance. It should be recorded that the cow was not in good flesh at the beginning of the experiment. She was continued for 2 weeks longer to see if she would gradually accustom herself to the water. It became apparent, however, that she would die. She was then changed



COW NO. 1, a Guernsey, received 1.75% sodium chloride water for 15 weeks and 2 percent sodium chloride solution for 7 weeks thereafter. Picture was taken at the end of the 8th week.

*Composition of this ration may be obtained from the Dairy Department of this Institution.

back to city water to ascertain if she had been permanently injured. She consumed much water. Her appetite gradually returned. She gained in weight and in less than 30 days was about normal. At that time she was sold on the open market.

Table 6 contains the data of a long time test of animals receiving tap water as controls as well as various levels of sodium chloride.

These cows were all large, well-bred Guernsey and Holstein cows whose histories were known. All had been in the College herd for several years and were never accustomed to salty water. No. 4 produced 30 to 40 pounds of milk daily during this entire period. No. 2 and No. 3 gave birth to calves during the period and produced similar amounts of milk thereafter.

In all cases, the animals refused to drink much during the first week of the experiment and records were not kept until all were somewhat accustomed to the drinking supply. A comparison of the data shows that Cow No. 2 gave birth to a normal 86-pound calf during the seventh week of the experiment. The calf was permitted to run with the mother and was sold eight weeks later as a good veal calf weighing 220 lbs. The mother lost some weight during this period and was not in as good condition as previously, but maintained her milk production. At the end of 14 weeks she was turned out to pasture and given normal water, after which she exhibited no ill effects.

During the 13th week No. 3 gave birth to twin calves, weighing 45 and 50 pounds. One calf was weak, but both lived on the mother's milk and thrived as well as twin calves normally do. Their mother lost some weight.

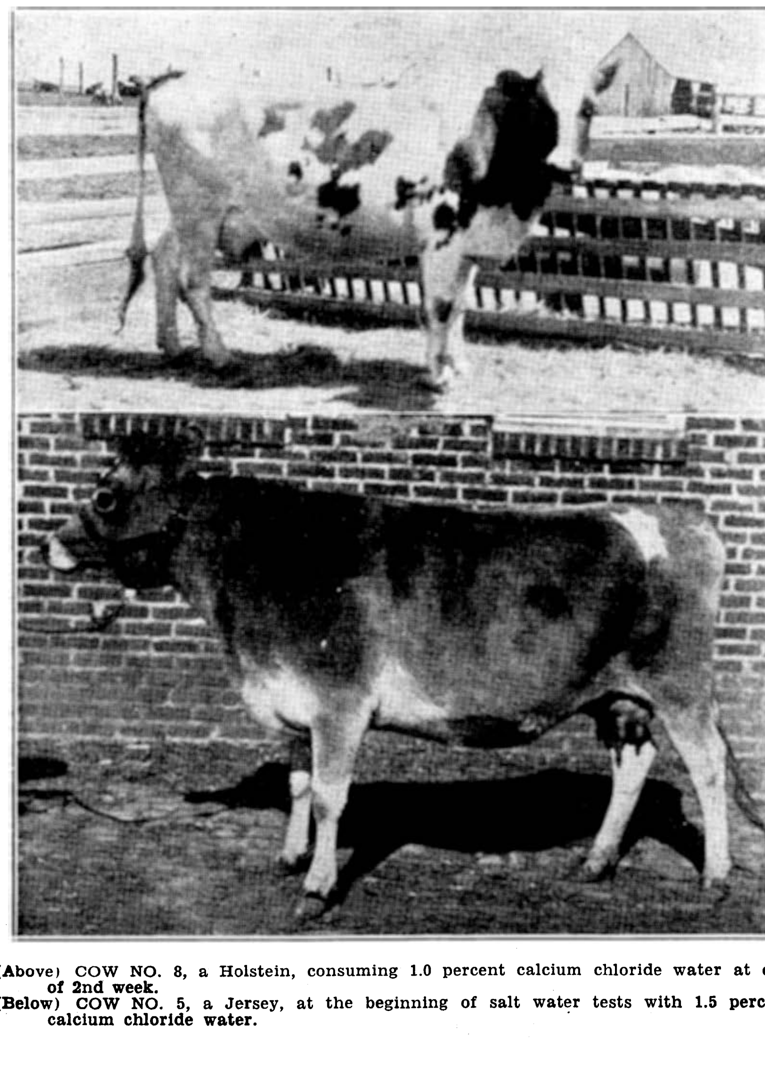
Cow No. 1 was given 1.75 percent salt for 15 weeks. During the entire

TABLE 6.—Weights and Average Daily Consumption of Water by Cattle on Pure Water and Various Concentrations of Salt Water

Week	Cow 1. 1.75% NaCl		Cow 2. 1.5% NaCl		Cow 3. 1.5% NaCl		Cow 4. Pure Water	
	Weight lbs.	Water gal.	Weight lbs.	Water gal.	Weight lbs.	Water gal.	Weight lbs.	Water gal.
1st	1068	4.3			1252	7.5		
2nd		8.7	1325	6.2		5.6	1394	9.5
3rd		6.3		7.7		6.4		9.1
4th		8.9		8.0		5.4		12.1
5th		10.4		13.9		10.7		12.3
6th	1055	6.1	*1118	12.3	1270	6.9	1268	9.0
7th	980	8.9		19.9		7.6		11.0
8th	1015	9.0	1170	15.9	1210	9.3	1262	11.0
9th		8.0		12.0		4.9		13.0
10th	990	13.0	1032	19.1	1146	7.6	1315	16.5
11th	965	8.4	1082	17.0		6.3		13.7
12th	1002	8.4	1070	16.7	**1232	9.7	1210	16.6
13th	1040	11.4	993	19.1	1110	8.1	1270	13.9
14th	1045	8.7		†	1020	9.5	1365	13.0
15th	1070	***9.6			970	12.0	1300	16.3
16th	995	7.9			869	14.6	1210	19.6
17th	1000	8.7			955	10.9	1235	17.7
18th	890	8.1			870	14.1	1325	18.4
19th	925	6.3			990	19.1	1247	17.1
20th	975	4.6			954	15.6	1292	19.3
21st	933	4.6			955	13.8	1251	17.0

*Calved. 86 lbs.
**Calved. Twins—45 and 50 lbs.
***Cow No. 1 changed to 2% NaCl the 15th week.
†Discontinued.

period she ate and drank normally. During this time she was dehorned and lost some weight for a period. This was regained, however, and at the end of this time she was in as good shape as at the beginning. The 16th week she was changed to 2 percent sodium chloride, on which she was continued for 7 weeks. These tests have been repeated often enough to demonstrate that steers and cows not in production can live on higher concentrations than cows in heavy production. Apparently, 1.5 to 1.75 percent sodium chloride water can be consumed in these cases without serious results. For cows in heavy production, 1.5 percent seems to be slightly more than can be consumed with normal maintenance. The most interesting observation is



(Above) COW NO. 8, a Holstein, consuming 1.0 percent calcium chloride water at end of 2nd week.
(Below) COW NO. 5, a Jersey, at the beginning of salt water tests with 1.5 percent calcium chloride water.

that in no case has abortion taken place, although the cows were well advanced in pregnancy and no precautions were taken in making the changes. Calves were born at the regular time and developed normally.

In the earlier experiments with rats it was found that calcium chloride gave results similar to those produced by sodium chloride. When tests were made with chickens the calcium salt seemed to be less well tolerated. The tests were repeated with cattle, as it is the second most prevalent salt found in most Oklahoma waters. The tests have been repeated three times—during the cold winter, during the heat of early summer, and during the fall months. Both producing and non-producing cows have been used, and in all cases the results have been the same. Solutions of calcium chloride possess a bitter stinging taste. It seems to be so offensive to cattle that days passed before they would drink at all and then in quantities insufficient for normal needs of the cows. Feed consumption decreased and the cattle lost weight. From these observations, it is difficult to conceive of cattle ever consuming such waters except under the most drastic conditions.

Cow No. 5 was given water containing 1.5 percent calcium chloride as a sole source of drinking water. As time passed she drank less and less. Food was refused and the animal became nervous. She finally refused the water entirely on the 28th day and drank no more for 12 days. During this period she lost 100 pounds in weight. When it appeared that a continuance of the test would soon prove disastrous, she was returned to normal water to determine whether or not she had been permanently injured. Water consumption was heavy and food intake soon became normal. In one month the cow had regained her lost weight and was again normal.

Cow No. 6 consumed the same solution. She likewise lost in weight, refused to drink sufficient water, refused her feed, and was discontinued when it became apparent her record was similar to those previously tested. Her recovery was in every way similar to that of Cow No. 5.

Cow No. 8, which was in heavy milk production, was given a 1 percent calcium chloride solution. This water also appeared to be distasteful. The conditions were not as unfavorable as for those drinking a 1.5 percent solution, but she refused to drink more than one-half as much as she had of the normal water. She refused a portion of her feed for a while. Her milk production decreased somewhat more than it would have due to continued period of lactation. When it became apparent in about four weeks that she had reached a condition where little further change would take place either way, she was transferred to normal water without any restrictions and without any apparent shock. Both feed and water consumptions greatly increased, while the milk production showed some response. At the time of writing, she is being used as a family milk cow and will be continued in that capacity during the normal lactating period.

Cow No. 7 was given saturated calcium sulfate solution. Although she refused it for a time, she soon became accustomed to its use and no ill effects were noted. It should be remembered that this compound is relatively insoluble and not enough would go into solution so that the resulting water could be placed in the class of heavily saturated waters.

Chemical Analyses of Blood

The fact that all animals seem able to adjust themselves to a limited extent to waters that would have injured them if they had been consumed without any introductory period suggests that some change must take place in the composition and physiology of the body. It is usually thought that under normal conditions the concentrations of calcium, magnesium, sodium and chloride are almost constant in normal animals; yet conditions in these animals suggested that some changes in osmotic pressure must take place. For these reasons, animals from the control and salt water pens have been bled from time to time by heart puncture or from the jugular vein. The

TABLE 7.—Water Consumption of Cattle on Calcium Chloride and Calcium Sulfate Waters

	Cow 5. 1.5% $CaCl_2$		Cow 6. 1.5% $CaCl_2$		Cow 7. Conc. $CaSO_4$		Cow 8. 1% $CaCl_2$	
Day	Weight lbs.	Water gal.	Weight lbs.	Water gal.	Weight lbs.	Water gal.	Weight lbs.	Water gal.
1st		3	792	1	850	7	1210	4
2nd		8		7		6		2
3rd	880	7		8		4		4
4th		0		6		5		2
5th		0		9		8		2
6th		0		4		4		2
7th		10	615	0		10		4
8th		4		2		8		2
9th		0		12*		8		2
10th		2		10		9	1120	4
11th		3		13		6		4
12th		0		4		8		4
13th		3		3	865	8		8
14th		0	641	5		7		4
15th		2		7		6		8
16th		0		7		7		0
17th		0		6		7		4
18th		0	709	3		4		4
19th		10		†		13		8
20th		4				5		0
21st		0				8	1090	2
22nd	850	2			855	6		2
23rd		3				11		2
24th		0				5		4
25th		3				6		4**
26th		0				6		4
27th		2				6		8
28th		0				7	1110	10
29th		0			878	4		
30th	830	0***						

*Cow No. 6 changed to city water.
**Cow No. 8 changed to city water.
***Cow No. 5 from 31st day to 40th day drank no water; weighed 725 lbs. on 39th day.
†Discontinued.

cells and serum were quantitatively separated and analyzed for the common inorganic ions. The most recently accepted methods of blood analysis have been employed as follows: for sodium the method of Butler and Tuthill,[3] for potassium the method of Shohl and Bennett,[14] for calcium the method of Roe and Kahn,[12] for magnesium the method of Briggs,[1] for chlorine the method of Van Slyke,[15] and for sulfate the method of Cuthbertson and Tompsett.[5] The results of these analyses have been averaged and the data presented in Table 8. An inspection of these results reveals that the percentage of an ion in any blood is usually rather fixed and very little change is found for that species of animal under the normal condition of health. It was observed, however, after many analyses had been made, that occasionally a marked change is produced. It was found that there was an increase in the sodium and chloride content of the blood of chickens which had been on a high salt diet for a long period of time and were apparently at the point of death. Whether this condition was produced by the approach of death or death was caused by that change cannot be answered at this time. The same observation was made in the case of the hog the day previous to its death;

to a less extent in the case of sheep; and in the case of the 2 percent salt water cow, although she was in apparent good health at the time of bleeding. In all, several hundred analyses have been made and as a result it can be stated that there is very little change in the concentration of sodium, potassium, magnesium, calcium or chlorine under normal conditions or even when considerable amounts of salt are consumed. The changes here recorded are the rare exceptions at the time of critical condition. However, as the maximum tolerance is approached changes are observed. Death often takes place soon thereafter. The exact cause of the injury is still an unanswered question. The data have been summarized and are presented in Table 8.

TABLE 8.—Blood Analyses of Animals on Salt Waters
(mg. per 100 cc.)

Salt Concentration	CHLORINE			MAGNESIUM		SODIUM	CALCIUM
	Whole Blood	Plasma	Cells	Plasma	Cells	Plasma	Plasma
A. Rats							
Control Pen (Normal)		340	238	6.7	3.3	332	10.3
1.5% sodium chloride		351	243			339	9.8
1.5% sodium hydroxide		344	239			342	9.9
1.5% calcium chloride		342	239				10.0
1.5% magnesium sulfate				6.8	3.8		10.2
1.5% calcium hydroxide							9.9
1.5% calcium sulfate							9.8
B. Chickens							
Control Pen (Normal)	334	375	270			355	*
1.5% sodium chloride	350	392	284			386	*
2.0% sodium chloride	380	443	280			408	*
C. Sheep							
Control Pen (Normal)	302	380	233			347	**
1.5% sodium chloride	354	422	286			375	**
D. Pigs							
Control Pen (Normal)	271	313	206			334	10.2
1.5% sodium chloride	327	387	258			387	10.0
E. Dairy Cows							
Control Pen (Normal)	300	341	227			356	10.0
1.5% calcium chloride	315	370	241			352	9.5
2.0% sodium chloride	345	396	258			384	9.6

*Calcium values fluctuate normally in laying hens and cannot be used to judge changed conditions.
**Calcium values not determined.

SUMMARY AND CONCLUSIONS

1. Analyses of hundreds of samples of water from Oklahoma and adjoining states show that many waters are heavily saturated with sodium, calcium and magnesium chlorides, calcium, magnesium and sodium sulfates, minor quantities of carbonates, bicarbonates and other ions in smaller amounts. These waters come from naturally occurring springs, deep wells, and from oil well pollutions.

2. Carefully controlled experiments with rats, chickens, hogs, sheep, and cattle have proved that animals compelled to drink solutions sufficiently saturated with these salts are injured.

3. In no case has it ever been found that any animal ever chose to drink a water that was harmful if good waters were accessible.

4. The damage seemed not to depend so much on the kind but the amount of the salt present, the total soluble salts present being the important factor. It made little difference if the quantity was made up of a single salt or a number of them.

5. The limit of tolerance depended upon the kind of animal, age, season of the year, whether in milk production, etc. The inability to suckle young was noted before any injury to the mother was apparent.

6. Sheep were more resistant than cattle and cattle more so than hogs. The fact that the sheep were raised in a hard water country might have been a factor. Sheep have been able to exist on 2.5 percent solution of sodium chloride and 2 percent magnesium sulfate. Cattle not in milk production have maintained themselves on 2 percent sodium chloride solution. As a safe rule, however, it can be said that 1.5 percent total salts should be considered the upper limit under which maintenance can be expected. For lactating animals the limit is lower.

7. Sodium chloride is somewhat less active than calcium chloride and magnesium chloride is the most injurious, the injury coming evidently in the limited amount of water the animal will consume. The alkali solutions are more injurious than saline waters, the injury being more direct as a chronic enteritis is apparent. An alkaline water should be used with care. However, saturated calcium hydroxide solutions have been used through three generations of rats.

8. Animals can become accustomed to drinking waters not possible to consume at first. Egg and milk production are decreased during the adjustment period and there is a limit, as designated above, beyond which no further adjustment is possible.

9. Blood analyses fail to demonstrate any marked changes in the composition of the blood that might be responsible for such an adjustment, although it has been found that just previous to death some changes do take place in the concentration of sodium and chlorine. Whether these changes were due to the approach of death or death was produced by the inability of the body to maintain longer the constant composition is a debatable question.

10. It is not the purpose of this article to recommend saline waters, as a water supply free from all salt contaminations should be obtained if possible, but rather to determine under what extreme conditions growth, reproduction and maintenance might be possible if the animal were compelled to use such a water as a sole source of drinking supply.

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