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Water Quality for Animals

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WATER QUALITY FOR ANIMALS

THE PURPOSE OF THE SYMPOSIUM

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THE PURPOSE OF THE SYMPOSIUM

Water is one of the most essential parts of our physical being. Man, animals, plants and all living life could not survive without water. Water is essential to maintain life, not just through physiological processes of the body but through the sanitation and maintenance of the environment surrounding us.

Water quality has been impaired since man inhabited the earth. For survival, man located his domicile near water, not just for his need to quench thirst, to cook and to bathe, but also to dispose of his refuse. Thus, civilizations were started near bodies of water, particularly flowing water. Prior to the entrance of our ancestors to this country, the Indians also located their camps near waterways. From this started the city dump as we knew it a few years ago, and only recently removed from the scenes of our civilization. Man has polluted waterways of America in his move towards civilization. Pollution from chemicals, bacterial and viral agents and the refuse from man--all have been found in streams. Yet, man's strides towards civilization was preceded by the organic pollution of waters from floods, plant life and animal refuse. So man alone can't be the sole contributors of waters of poor quality.

Different means of water purification accompanied the progress in the improvement of our way of life. Purification was accomplished by boiling and by chemical disinfecting. The criteria established for water quality was that established by public health authorities for human's use and equated the amounts of chemicals and microorganisms that were considered safe for human consumption. To obtain this, various means of water purification were instituted.

Today, most water consumed by humans in any recognized municipality meets standards set up by State and Federal Departments of Health. However, the waters in our rural areas are not monitored by any recognized agency. Water purification systems are available and frequently used in rural water supplies. However, it is estimated that over 30 to 50 percent of our rural water supplies do not meet public health standards.

Likewise, the standards applied to water quality for humans has also been applied to water for animals if any standards are used. In many cases, waters of various qualities are used with little if any concern as to their effect on animal health or performance. The void in our knowledge is the quality of water necessary for maximum animal performance.

The health of animals is mandatory in order to supply the animal protein needs of the people in this country. Water is an absolute necessity in the production of animals. It is time that the quality of water necessary for maximum animal performance be determined.

The purpose of this symposium is to determine the role of water in animal performance and to establish standards of quality if such standards are available. The objective of establishing standards or minimum quality criteria is necessary to supply uniform testing procedures for laboratories and to provide standards for water installation units for producers as well as for installers of water purification equipment.

PHYSIOLOGICAL ASPECTS OF WATER IN ANIMAL PRODUCTION

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PHYSIOLOGICAL ASPECTS OF WATER IN ANIMAL PRODUCTION

We consider that life originated in the oceans, an aqueous or watery environment, during early evolutionary periods. Cells and multicellular organisms were bathed in a fluid that corresponded quite closely to what we consider as the extracellular fluid of the body, with relation to its electrolyte content. By electrolyte we mean the dissolved ions that are present for example sodium, potassium, calcium, or chloride. When animals began to move into fresh water they faced the problem of keeping fluids out of their bodies as water tends to move by osmotic gradients from the more dilute to the more concentrated compartment. As evolution continued and the animals moved onto land, there were faced with the even greater problem of obtaining and conserving water.

All land dwelling species are absolutely dependent on water. In a consideration of the physiology or function of water, with relevance to domestic animals, it is important to first realize that water is the major component of the body. Water comprises approximately 60-65% of the mass of most farm animals. It is absolutely essential for life and well being.

Adult humans and adults of the common domestic species have similar body composition with regard to water. Humans and pigs are the least hydrated animals which is a function of deposition of fat.

Animal	Total Body Water ml/kg
Cattle	660
Pigs	500
Chickens	570
Dogs	610
Cats	620
Rabbit	710
Man	520

Water must be present in the diet for life, growth, reproduction and well being. What happens to water when it comes in contact with the body? How does it get in? How does it get out? The principal route of water acquisition is by mouth or drinking. The impetus for an animal to consume water is the feeling of thirst. Several factors relating to water balance, salt balance and temperature have an effect on a portion of the brain, the hypothalamus. When the hypothalamus is stimulated by decreased water volume or increased salinity in the body, nervous impulses are transmitted and hormones are released which result in several responses.

(1) THIRST

(2) WATER CONSERVATION

Thirst, the desire to consume water is noticed as a decrease in salivary output, the sensation of a dry mouth. There is also direct stimulation of the thirst center. When water is subsequently consumed and enters the digestive system, we still consider that it is outside the body. It next must move across the cellular barrier and enter the blood stream. In addition to water consumed by drinking there are other sources of water for the body. One is the water which is present in all food that animals consume. Some feeds like green grass and silage contain large amounts of water. Others obviously provide only minimal quantities. One last source of water exists. It is termed metabolic water. This is the water formed as a result of the oxidation of carbohydrates, lipids and protein. Carbon dioxide and water are the final products of oxidative metabolism.

Water conservation is a function of the kidneys. They have the capacity to continuously excrete body wastes in the form of either a dilute or a concentrated urine. Which occurs depends on the overall water status of the body. If water is limited and a degree of dehydration is present, the kidneys are capable of forming a very concentrated urine with a large amount of dissolved substance. Conversely, if there is an excess or even a plentiful supply of water, a more dilute urine is formed. Water is also lost from the body through the skin, the insensible water loss. It is greatest in hot weather, and in those animals such as the horse and man that have large numbers of sweat glands. In all species, water is continually lost from the body by this route.

Water is also lost with each breath. The air that is exhaled when we breathe is saturated with water. Air is capable of holding more water when it is warmed. Generally the exhaled air is warmer than the inhaled air and therefore contains more water. Coupled with this, it is rare that the humidity is 100%. Inhaled air, therefore, gains water both by being warmed and being saturated. The result, a net loss of water due to respiration.

Once water enters the body it mixes with and becomes inseparable from water that is already present. We can consider this from the standpoint of pool characteristics. The amount of water present at any time is considered to be "the pool." In an animal that is not growing, the pool size remains quite constant over a wide range of conditions. Yet the water in the pool is continually changing. We call this continual flux <u>turnover</u>. The water turnover for a given animal can vary greatly as you might imagine. For instance during cold weather when water losses are less, water turnover is decreased. A dairy cow may have a tremendous change in her water turnover following parturition and the initiation of lactation as shown in the following table.

Holstein Dairy Cow	Water Consumption ml/kg/day	Water Consumption ml/kg/day	Total Turnover 650 kg cow
non-lactating	60	67	43,550 ml
lactating	148	159	101,400

Total body water, the water pool, varies with age and with body composition. In essence animals are born in a relatively highly hydrated state, and slowly dry out as they age. Most people are aware of this phenomenon even if they have not considered it. Veal from young calves is a very moist meat while meat from an aged dairy cow or a range bull is a pretty dry substance. A newborn animal may be up to 80% water, while a mature or aged animal may contain only about 50%.

Water content does vary considerably between species and between individuals. This variability is related directly to the fat content. There is virtually no water in fat. An obese animal, such as a pig with a 35% body fat content might have only 35-40% water in its body.

Body water is furthur compartmentalized into that found inside cells (intracellular) and that found outside cells (extracellular). They represent 2/3 and 1/3 of the body water respectively.

Even though these compartments are in a constant equilibrium they serve different purposes. Intracellular water can be considered as the basis of the cellular matrix. Extracellular water provides the principle transport route to carry nutrients to cells and waste products away.

Water in the body serves a number of important functions. We will discuss briefly a few of these. First, water serves as a solvent to keep important nutrients and metabolites in solution both inside and outside cells. Water is the dissolving substance that

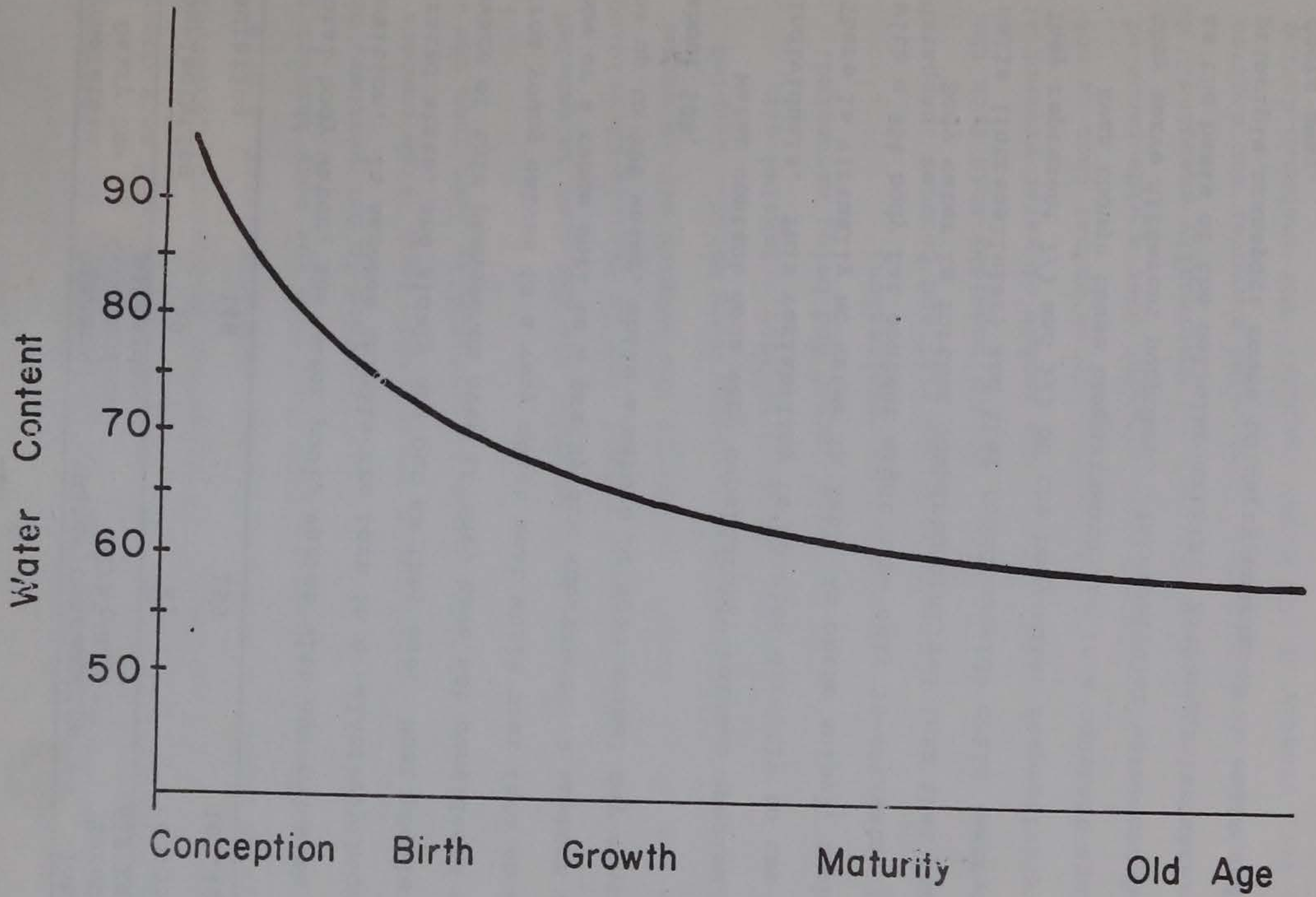

FIG. 1. CHANGE IN PERCENT BODY WATER CONTENT WITH AGE

allows the formed elements of the body to interact. Inside cells it provides the fluid matrix that gives form to each individual cell. Cells are, in essence, fluid filled membranes which assume a roughly spherical shape. The shape varies with cell type, location and condition. The membranous sac around each cell is a complex of lipids and protein which act to selectively include and exclude other constituents of the body from the cells interior. For lack of a better name we call these proteins that concentrate certain substances on one side or the other of a membrane as active transport proteins or cellular pumps. They do not pump water however. They pump a variety of solutes such as sodium, potassium, glucose, amino acids (the basic constituent of protein), while water movement across membranes is passive. It is dependent upon the active transport of other substances which develops a diffusion gradient or osmotic gradient.

These cellular pumps are very analogous in action to any other pump. That is, they move a substance in a direction which it would not normally go. Also, like other pumps, they require energy to operate.

The net result of the activity of these pumps is that certain of the body's constituents are highly concentrated inside cells. Because of this concentration gradient, water follows in order to maintain an osmotic equilibrium. The water, flows passively across membranes. The sole factor which determines its net directional movement is the concentration of substances. Therefore, if material is pumped into cells, water will flow into cells. This essentially develops the spherical shape of the body's cellular elements. As concentration increases due to pumping, water enters forming a "typical contour" for that cell. Of course, the water also serves as a solvent and carrier for nutrients that the pump must continually receive in order to operate.

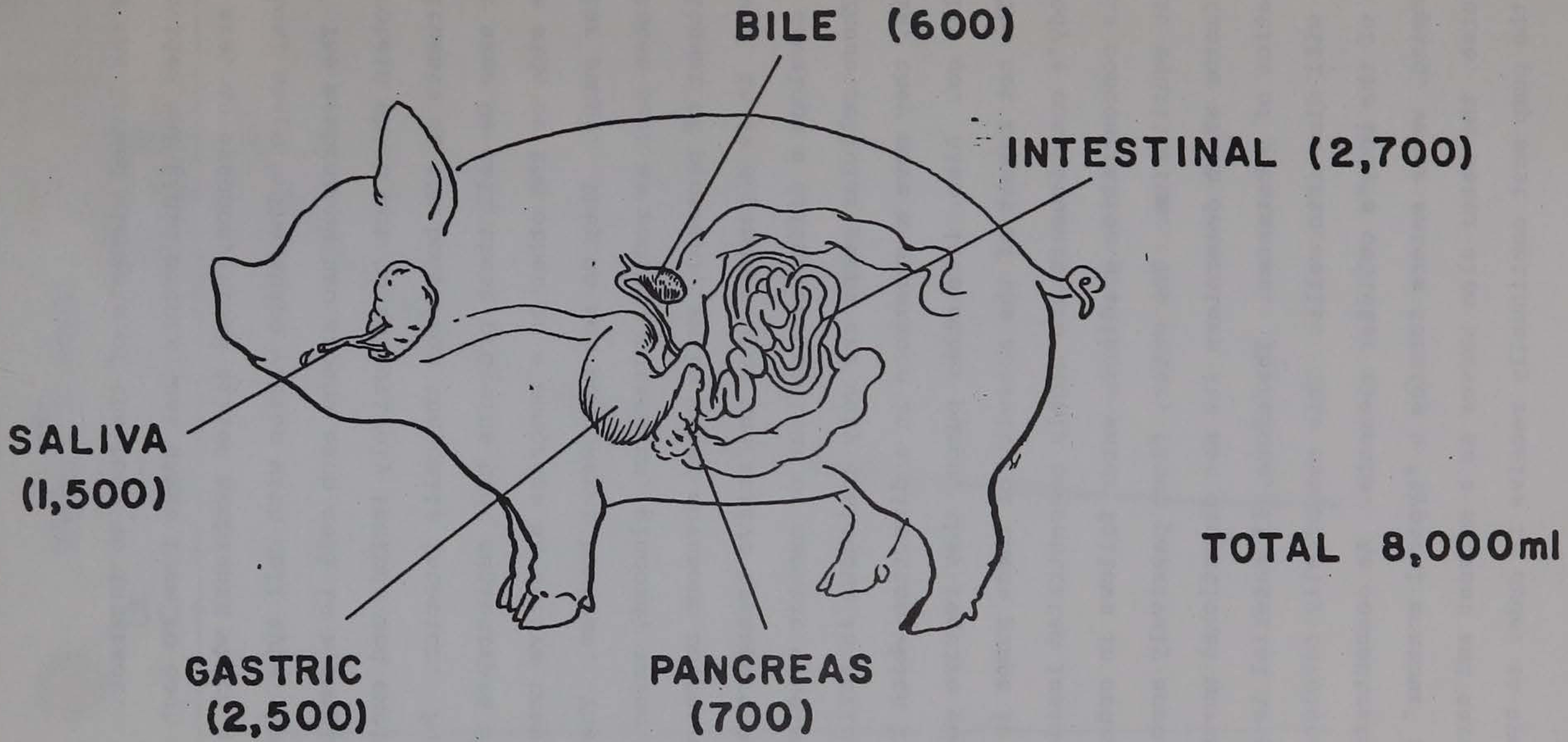

FIG. 2. DAILY FLUID SECRETIONS INTO THE GASTROINTESTINAL TRACT IN MILLILITERS

Another transport function of water in the body is to help in the process of moving food nutrients through the digestive tract, the blood, and the interstitial spaces to the cells of the body. As food is taken in via the mouth it is solubilized and mixed with water which is added via salivary secretions, from the stomach and from the intestinal tract. From a volume standpoint, the body secretes into the gastrointestinal tract 5 times as much fluid as is taken in by drinking or eating moist food. As an example a 80 kg gilt would secrete about 10% of its body weight/day, or about 8000 ml. This quantity is even larger in ruminants such as the ox or the sheep. They have a tremendous rate of salivary secretion up to 30% of their body weight can be secreted every day just as saliva. An adult cow may secrete 200 liters in a single day. This is essentially the equivalent of a 55 gallon drum just of saliva. The water in this secretion aids in rumen function and absorption of nutrients from the rumen. The majority of this secretion is reabsorbed during digestive processes.

There is another aspect of water function that should be mentioned. Water is, of course, the major constituent of the blood, as such it is intimately involved in a continual transport process throughout the body. There are tremendous rates of flow of this aqueous fluid through the cardiovascular system. In man the resting cardiac output is 5 liters/minute or 300 liters/hour or 7,200 liters/day. This amounts to over 1900 gallons, or close to four tons of blood is pumped/day by each of our hearts. That's just at rest. The cardiac output may increase 4 or 5 fold during heavy exercises. This flow of blood is essential for viability and life of the tissues of the body.

There is one final aspect of water that we should consider as it relates to function of animals. This is concerned with some of the physical attributes of water and how they are of benefit to biological systems.

The first to consider is heat capacity. That is the temperature change in a substance as it absorbs heat. Water has one of the highest heat capacities. It takes more heat input to raise the temperature of water 1 degree than any other substance. This fact is of benefit in both heat exposure and cold exposure as it minimizes body temperature fluctuations.

A second important physical characteristic of water is its high heat of vaporization 580/calories/gram of water. This allows animals that are exposed to heat, or have an increase in body temperature, to dissipate that heat by evaporating water. This is part of the insensible water loss that we discussed earlier. If water evaporates from the skin as it is formed we are not conscious of its occurrence. Only when sweating becomes profuse and occurs more rapidly that it can be evaporated do water droplets appear. This is of course a more common occurrence in regions where high humidity prevails and evaporation is reduced. Evaporative cooling is a major mechanism of body temperature control in domestic animals.

The last physical characteristic that we will discuss is the viscosity of water. It has a relatively low viscosity which is important in facilitating flow through the cardiovascular system. In order for flow to proceed through the miles of small tubes which comprises the cardiovascular system a low viscosity, high flow rate fluid is necessary. When you consider that on an average the total quantity of blood present in the body is circulated every minute, it is apparent that significant modifications would have to be made in the pump (heart) or the tubular system (arterys, veins) if a high viscosity fluid were being circulated.

In summary there are several important characteristics of water that should be considered from an overview of its function in the body.

1. Quantity, it is the most abundant constituent of the body.
2. Solvent, water as the universal solvent serves as the carrier of nutrients and waste products.
3. Turnover, water is in a constant state of movement into and out of the body, circulating within the body, and circulating into and out of cells.
4. Physical characteristics, due to water's low viscosity, high heat of vaporization and high heat capacity it contributes to the ability of animals to withstand a variety of environmental conditions and yet maintains a stable care environment.

From a specific standpoint of animal production several additional factors should be considered. First is palatability, the acceptance of the provided water. In cold weather animals tend to drink less, which can result in disease conditions particularly in early castrated cattle and sheep. Water that is warmed will be more readily consumed. Also associated with palatability is the level of dissolved substances present in water. In several areas of the country dissolved or suspended inorganic and organic nutrients may affect palatability as well as initiate disease or dysfunction through toxic manifestation. The role of dissolved substances in supplying valuable nutrients as well as potentially detrimental compounds however, is outside the scope of this presentation.

PROBLEMS ASSOCIATED WITH RURAL WATER SUPPLY

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PROBLEMS ASSOCIATED WITH RURAL WATER SUPPLY

Livestock and poultry producers with private water supplies can experience an economic loss if they do not provide a safe, adequate water supply for their animals. The importance of a good water supply is many times overlooked in the management of a livestock enterprise. Each producer must be made aware that he is, in effect, the water plant operator for his individual animal industrial plant. He should be ever mindful of the water supply system and the quantity of water delivered to his animals.

Providing adequate quantities of water meeting quality standards from private water systems may be a difficult task in Iowa and many other midwestern states. Groundwater sources are often limited and water quality may not be acceptable without treatment from many groundwater formations. Surface water sources must be adequately designed and protected from contamination and treated to provide a safe water supply.

Other papers in this proceedings deal with the quantity and quality requirements for animal water supplies. Failure to meet these requirements will lead to lower productivity, possible animal health problems, and a lower economic return from the enterprise.

Problems commonly associated with a lack of adequate supply of water are reduced feed intake and a resulting lowering of production. Water of substandard quality may result in poor acceptance and a lower intake of water causing production loss or it may result in an animal health problem as a result of mineral or organic contaminants. Water supply problems can disrupt efficiencies of production systems and place animals under stress. Many research results have been documented to relate performance with water supply. For example, Iowa results indicate that hogs supplied water from automatic waterers gained 10 pounds more per animal than hogs watered twice daily. Dairy cows watered automatically drank 18 percent more water and gave 3.5 percent more milk than cows watered twice daily.

Water Supply Problems

Groundwater is the major source of water for livestock in the Midwest as well as the United States. Many areas of the Midwest are not blessed with large reserves of high quality groundwater. To understand groundwater resources, we must look at the bedrock formations from which we obtain water. Figure 1 shows a generalized map of the surface bedrock formations in Iowa. The surface of the bedrock formations slope to the south and west across Iowa. Much of the area with surface bedrock of Pennsylvanian age does not have good groundwater supplies except from small drift aquifers. In Iowa, this area is generally in the south-central and southwestern parts of the state (Figure 2). Here most wells are in the 2-20 gallon-per-minute range and many are not reliable water supplies in extended periods of dry weather. Areas underlain with other bedrock formations generally have a better chance of having a reliable groundwater source. Even though there are areas of the state where high capacity wells (>500 gallons per minute) may be found, the majority of farm wells will provide less than 20 gallons per minute (gpm). Large livestock operations may be curtailed in areas where higher capacity wells cannot be located. For example, a 5000-head beef feedlot should have a water supply capability of approximately 18 gallons per head per day or a total of 90,000 gallons of water per day! If we design a system to pump 12 hours per day to allow for emergency capacity and a reduction of pumping efficiency with time, we would need a well yield of 125 gpm. This capacity well is not available in much of Iowa and other parts of the Midwest. Multiple wells or surface water may have to be used to supplement water supplies for such demands.

Surface water supplies are available in some areas with high annual runoff rate and where topography is suited for storage sites. This area in Iowa is generally located in south-central and southwestern Iowa (Figure 3). Fortunately, much of the area where adequate groundwater supplies are not available is located where surface water supplies can be developed. Reservoirs must be properly designed to assure adequate water storage during prolonged dry periods. Most problems occur when reservoirs do not have adequate capacity or do not have a sufficient watershed area from which water may be harvested.

Water Quality Problems

The most common groundwater quality problems affecting livestock production in the Midwest are:

(a) highly mineralized water sources,

(b) high nitrogen content of some supplies, and

(c) bacterial contamination.

Bedrock formations in the south and western parts of Iowa contain high levels of total dissolved solids (TDS). Rarely does the TDS level exceed 4500 mg/l. Since most domestic animals can tolerate TDS levels of 5000 mg/l, this is not a significant problem in itself. However, sulfate levels are highly related to TDS levels. Sulfate levels exceeding 500 mg/l are many times found in water from bedrock aquifers in these areas of Iowa. Figure 4 outlines areas where sulfate levels in groundwater may create problems with livestock production.

The occurrence of high nitrate concentrations is related more to improper well construction and location than to a particular groundwater region. Problems are most prevalent in shallow dug or bored wells with pervious casings and which obtain their water from glacial drift sand lenses or surficial sand and gravel deposits. Contaminated surface water enters these wells directly through pervious casings or after infiltrating only a short distance through surrounding soil. Nitrate problems may also be present in shallow aquifers near concentrated nitrogen sources such as septic tank leach fields, feedlots, or manure storage areas. Properly cased and sealed wells are unlikely to have any nitrate problems except in alluvial formations or in creviced limestone areas such as in northeast Iowa where aquifers may be in direct contact with contaminated surface water. Poor construction techniques for any type well may result in surface or other undesirable groundwater entering the well. Sanitary standards for well construction specify use of a grout seal between the bore hole and the casing of a well. In practice, this is seldom done for rural wells because of the extra cost involved.

Improper well and water system construction techniques are also the reason for most bacterial contamination problems. Filtration of water through 10-15 feet of medium textured soil material has long been considered to be an effective bacterial removal technique. However, in wells where the casing allows surface water entry prior to adequate soil filtration, bacterial contamination problems may exist. Groundwaters may also be bacterially contaminated in shallow gravel formations and in creviced limestone aquifers near the surface which allow surface water entry without adequate filtration.

Surface waters used for animals must be protected from several contamination sources. All surface waters must be assumed to carry high bacterial loads. University of Illinois researchers studied water quality in ponds with different watershed management practices. Fecal coliform counts in pond waters averaged 14.7 per 100 ml on grass watersheds, 145 counts per 100 ml on cultivated watersheds, and 982 per 100 ml on livestock watersheds. However, counts as high as 7200 per

100 ml were recorded after manure was applied to a cultivated watershed, and 16,000 per 100 ml during an intense runoff period from a livestock watershed. Grassed and cultivated watersheds reached maximum nitrate-nitrogen levels of 2.84 mg/l while ponds with livestock watersheds reached a maximum level of 22.0 mg/l nitrate-nitrogen.

Most surface water sources with protected watersheds yield water with low mineral content. If surface contaminants can be controlled, most raw pond water is adequate for livestock usage. Pesticide and fertilizer usage should be controlled in the watershed. If they are used on tilled crops, adequate soil conservation protection measures should be installed to control runoff and erosion. Recommended rates of application should not be exceeded.

Most surface water sources have problems with algal growth as a result of high nutrient loading in runoff water. A review of the literature reveals that blue-green algae poisonings of cattle, sheep and poultry have been reported in many of our north central states. Copper-based algaecides have been used most extensively to control algal blooms. Water should not be used for livestock immediately after treatment since livestock poisonings have been associated with rapid decomposition of algae cells.

Accidental Spills

Gross contamination of private water systems from accidental spills of petroleum, pesticides, fertilizers or other contaminants results in a major problem for users of private water systems. In some cases, supplies may be ruined for livestock drinking purposes for several years. Major causes of spills are overflow of unattended tanks being filled, back-siphoning from filling pipe back into well, or rupture of storage containers near wells or surface supplies.

There is no one solution recommended to treat accidental spills. Cleaning of the area of the spill to remove any contaminant on the surface should be performed immediately. If equipment is available, surface soil containing the absorbed contaminant can be removed to prevent excessive leaching to the aquifer. Once the contaminant breaks through into the well, continuous pumping will tend to eventually lower the concentration of the contaminant in the water supply. Samples of water should be sent to a laboratory to determine if harmful concentrations exist after extensive pumping. In some cases, treatment equipment may be installed to lower the concentration of a contaminant to a level where the water may be used.

System Design, Construction and Operation

A common problem with private water systems is inadequate capacity. This is especially true for expanding livestock and poultry enterprises. The water requirement grows beyond what was projected when the system was first installed. This observation illustrates the need to plan for expansion for new water systems. The components of a water system, well, pump, distribution system, and fixture should be compatible for an efficient design. Because of this, added demands on an existing system with limited capacity may result in shorter life of equipment, extra costs for energy, and inadequate pressure and flow rates at all points in the system.

Contingency or emergency plans should be developed for all private water systems supplying large numbers of animals. Many large operations have a backup system available in case of breakdown of the primary system. Others alternate systems monthly or semi-annually to maintain two systems in working order. Small operations may not use two separate systems but they should provide extra capacity in a system that can exceed peak demands to compensate for decreased efficiency over time and a longer equipment life. If only one source of water is available, an extra pump that can be immediately replaced when problems develop can prevent many potential livestock stress problems.

Construction methods are commonly determined by local water industry representatives. In some areas, these methods do not meet sanitary standards. A list of minimum specifications for well construction, pumping equipment, and distribution systems should be submitted to each contractor bidding on a job. Unless this is done, some contractors can underbid a job by lowering their standards below their competition.

A good management and maintenance program is necessary for a private water system to function properly. A common fault has been no maintenance or service on equipment until a problem develops. If water treatment equipment is required in a system, regular servicing is mandatory to assure delivery of a safe water to animals. Chlorinators on water systems need special attention. Fresh chlorine solution must be supplied to the feeder and chlorine residuals must be monitored at least weekly. Other treatment equipment should be inspected at least every 2 weeks.

Water Treatment Problems

Most groundwater supplies for animals are not treated prior to use. There are cases where water treatment is necessary or desirable. High iron and hardness levels may need treatment to prevent plumbing and fixture deterioration. Iron associated with iron bacteria can create pipe and valve clogging problems. Control of iron bacteria with shock or continuous chlorination may be required. If nitrates or sulfates exceed recommended limits from water sources, demineralization may be used to lower ionic concentrations. Distillation, electrodialysis, ion exchange and reverse osmosis units are currently available commercially. These units are seldom used with livestock water systems because of the relatively high unit cost of operation.

Many surface supplies may need bacterial control through chlorination. If turbidity of the water creates problems with plumbing fixtures or livestock waterers, alum feeders and coagulation chambers may be used.

Future Water Problems

Private water system users will continue to have problems in the future especially if we do not control further contamination of our water sources. In areas where groundwater quality is poor and quantities are limited, central water supply and treatment plants to supply water for rural domestic and livestock use will become more popular. Technology is currently available to provide more water and better water to our livestock operations now. We need to recognize the need for good water and commit ourselves to the task of improving our systems. We need further work on animal water problems, but we can take a big step forward if we use what we now know.

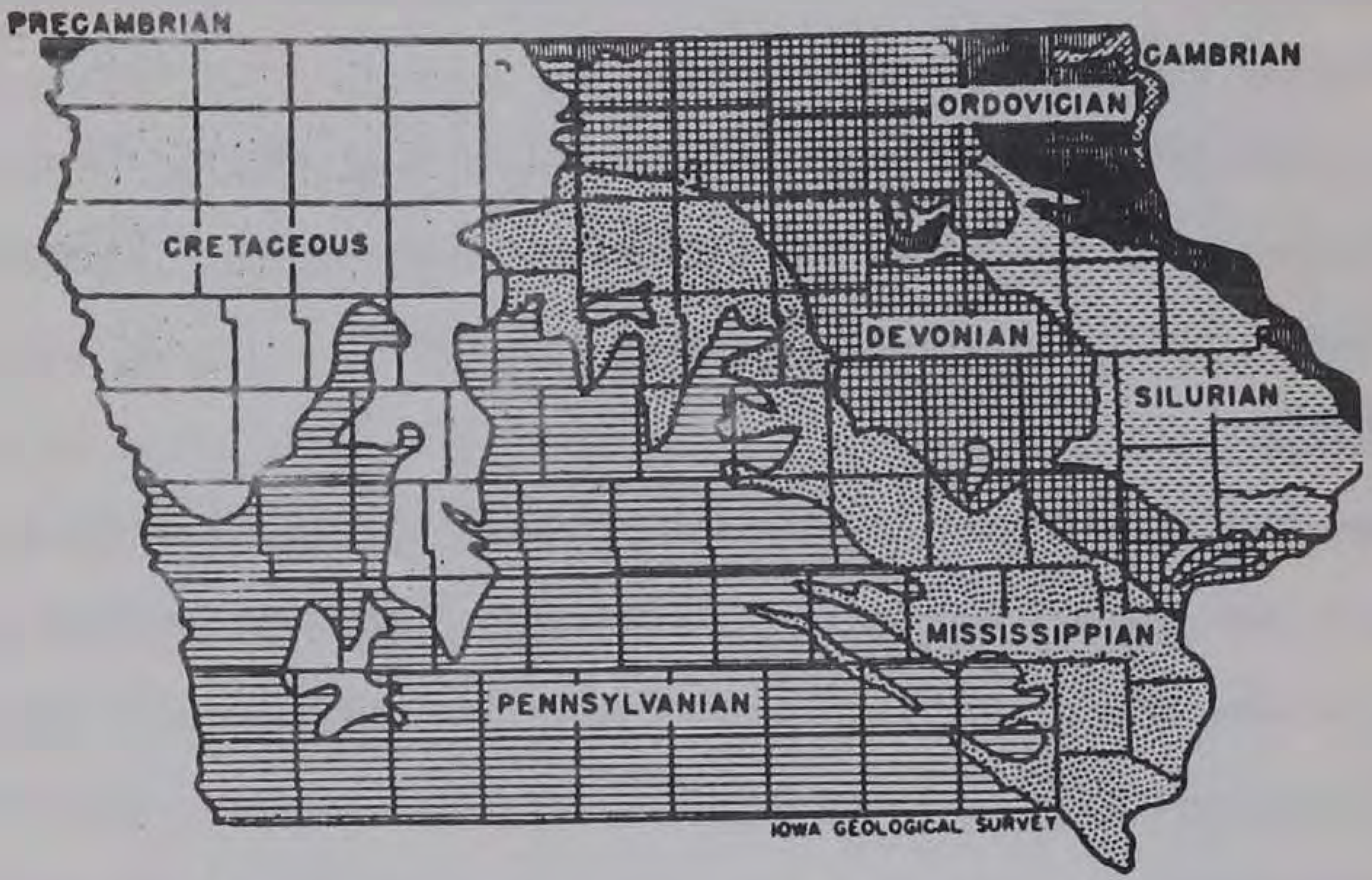

Figure 1. Generalized sketch map of surface bedrock formations (Source, Timmons et al. 1956)

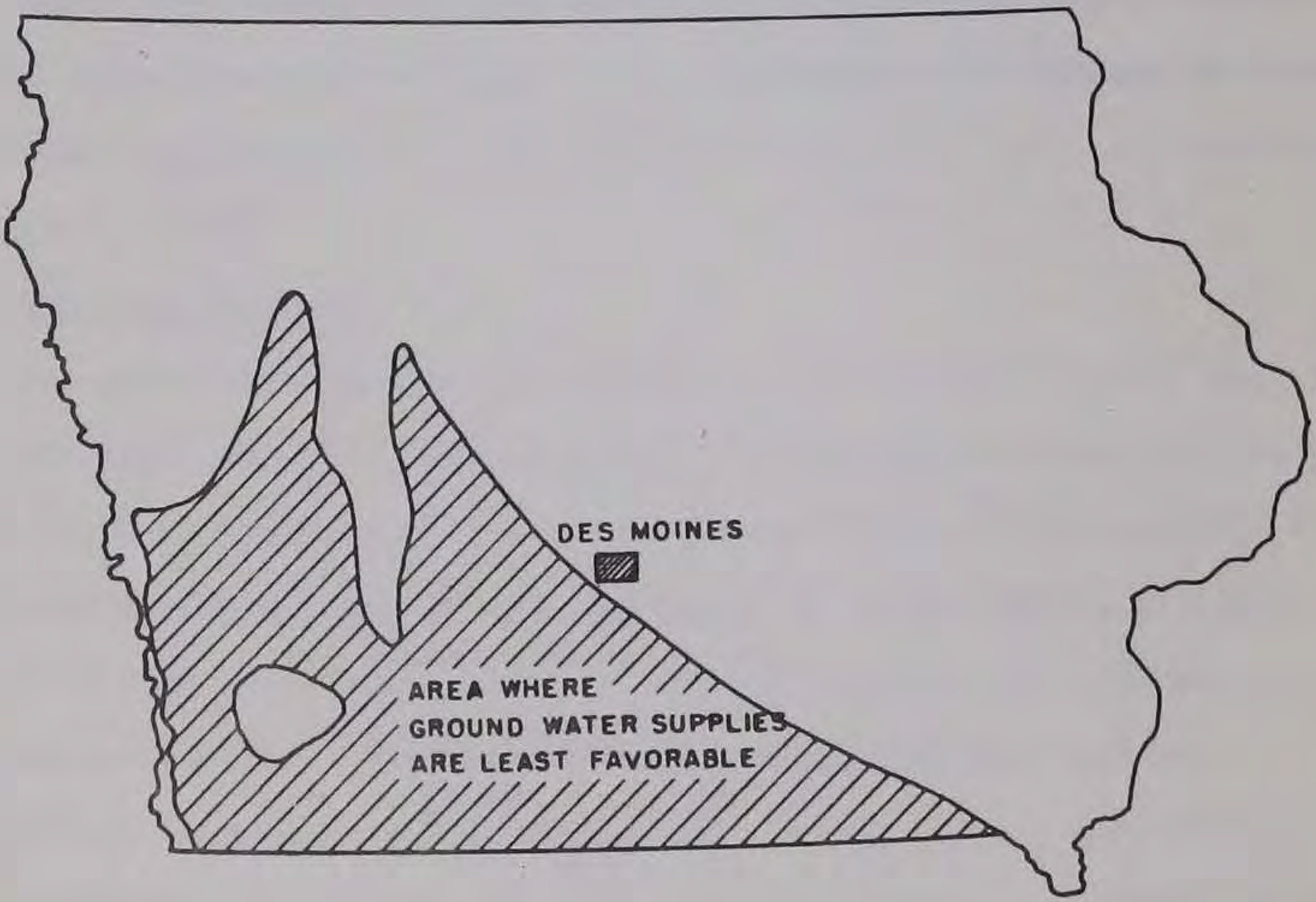

Figure 2. Area where groundwater supplies are least favorable in Iowa (Source, Willrich 1961)

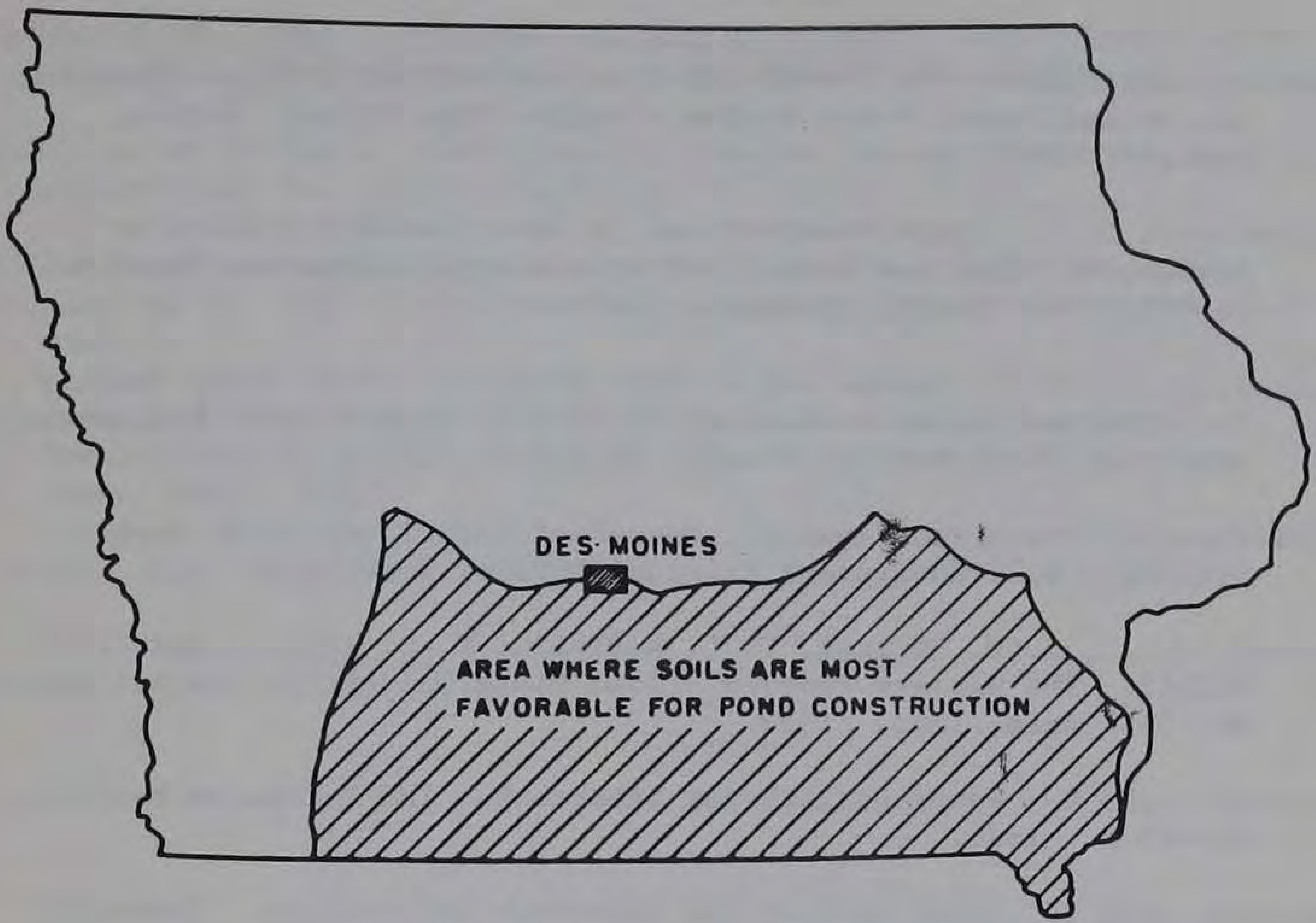

Figure 3. Area where surface water supplies most favorable in Iowa (Source, Willrich 1961)

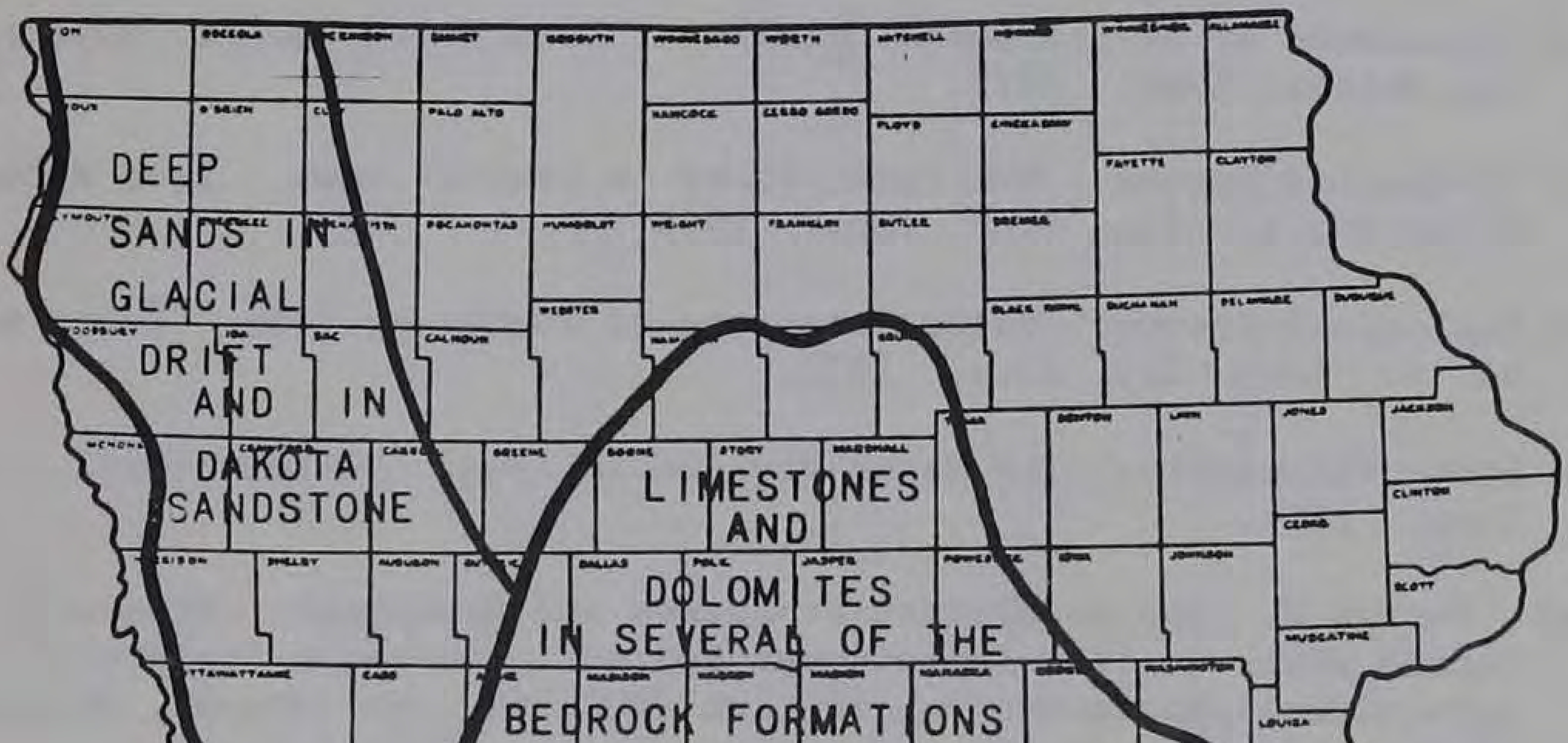

Figure 4. Areas where sulfate content of groundwater may affect livestock production

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WATER QUALITIES IN THE MIDWEST

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WATER QUALITIES IN THE MIDWEST

Introduction

A detailed discussion of the status and variability of both ground water and surface water quality in all the midwestern states would be a project of tremendous proportions. However, it does appear possible to approach the scope of the discussion to the level of one state.

In this case, I feel that the State of Iowa will serve as an appropriate reference point for a consideration of water quality in the Midwest. Iowa's commitment to agriculture is certainly representative of midwestern economic philosophy, and much of the emphasis in Iowa agriculture is on livestock production, whose success is closely tied to the quality of available water resources.

Even more importantly, Iowa is representative of midwestern states in the diversity of geological and climatological conditions which it exhibits. The extreme changes in weather and resultant alterations in surface water quality which occur in Iowa within even a single year must surely approach the range of conditions which exist in most midwestern states. The heterogeneous geological nature of the state has caused the quality of ground water available to agricultural users in different regions of the state to be nearly as variable as that on the surface.

Thus it is primarily this diversity in quality of available water resources within the state which justifies my use of Iowa as a point of reference in this discussion. The problems encountered in utilizing the various sources of water in Iowa for livestock watering should apply to nearly all midwestern livestock operations.

Water Resources in Iowa

As in any midwestern state, the two major sources of water in Iowa are ground water and surface water. The two main categories of ground water sources are the deep, sub-surface, bedrock aquifers and the more shallow surficial aquifers. Among the surface water sources, rivers and streams are most important to livestock production but lakes, ponds and reservoirs must also be considered.

The nature of the deep, artesian aquifers in Iowa can be simply characterized. They are usually located at a considerable distance from their recharge sources and movement of water within the aquifer is very slow. However, the quantity of water available in these bedrock sources is usually great. In fact they are probably our most productive water resource, and they can help to support baseflow at centers of ground water withdrawal.

Aside from these generalities, the character of a sub-surface aquifer may vary greatly. The composition and depth of aquifers in any locality is dependent on local geology which may differ appreciably even within short distances. A common example of this is the extent and nature of regional aquicludes which can profoundly affect the availability of the resource.

In terms of chemical composition, the water supplied by bedrock aquifers is usually consistent in quality and volume at any single point of discharge. Many wells from sub-surface aquifers are very high in content of dissolved minerals and the concentrations of dissolved materials vary considerably with locale.

The Mississippian formation, for example, yields consistently good water in the north central part of the state but its quality is less consistent in the southeast. In southern Iowa, dissolved solids concentrations of more than 3-4,000 mg/l are common, and levels up to 8000 are not unusual. In addition, the Mississippian formation is one of the aquifers that does yield high levels of fluoride.

Another good example of regional variation is the Jordan sandstone which is the most productive bedrock aquifer in Iowa. The Jordan formation is found in nearly the entire state and is used extensively in the eastern two-thirds. Concentrations of total dissolved solids from the Jordan are often less than 300 mg/l in northeast Iowa, but then increase toward the west and south. The Jordan formation provides water of less than 500 mg/l of dissolved minerals to twenty percent of the state and water of less than 1500 mg/l to sixty percent of Iowa. In many areas the deep Jordan formation is lower in mineral content than is the overlying bedrock layers. As such it can provide a good source of water where others are unsuitable. In these cases, wells necessitate careful construction to prevent intrusion and corrosion by the less desirable aquifers.

In summary, it can be said that better quality consistently occurs in north central, northeast, and eastern Iowa. The water in all the bedrock aquifers is much more mineralized in the south, southwestern, and western parts of the state.

The other category of ground water in Iowa is the surficial aquifer which includes both alluvial and glacial drift deposits. The alluvial and buried valley deposits are important sources of moderate to large water supplies, but they are restricted to river valleys and preglacial drainage lines. These shallow carbonate-rock aquifers have a close space-time relationship to streams.

Usually most of the water withdrawn from these sources is induced surface water.

These unconsolidated alluvial deposits may be very productive, and their near-surface locations usually allows economical development. As such, they are widely used for stock and domestic supplies, especially where underlying bedrock aquifers are highly mineralized.

The quality of water from alluvial aquifers is quite variable depending on the thickness of the aquifer and the depths of the wells. Quality is further dependent on the nature of the underlying aquifer or aquiclude and on whether water is from storage, induced filtration or local precipitation. Climatic conditions are closely related to water quality especially in view of the close association of alluvial aquifers with surface water.

This wide variation in quality allows little or no generalization about the chemical nature of surficial aquifers. Usually the total dissolved solids concentration is less than 500 mg/l but there are a few isolated areas in northwest Iowa where alluvial supplies produce water with a dissolved load of more than 1000 mg/l.

The surficial aquifers of the glacial drift are worthy of note because of their widespread occurrence. They are a source of water supply for numerous farm and rural homesteads throughout the state except in the extreme northeast where drift is largely absent.

Principally the drift is pebbly and sandy boulder-clay with a thickness of 0-600 feet. Glacial drift wells are usually fifteen to twenty feet deep, but some are as deep as 400 feet or more. In general, the yields from these wells are only a few gallons per minute, but with favorable conditions and good design, up to ten-twenty gpm may be possible. Chemically, the quality of glacial drift wells essentially follows principles established for alluvial deposits.

As mentioned above, the surface water resources of Iowa are comprised of rivers and streams, lakes and ponds, and reservoirs. Together they represent a valuable resource with significant usages varying from recreational and esthetic functions to actual consumption as drinking water. However, it does appear that use of surface water for agricultural purposes with controlled distribution is not widespread.

The relatively small number of lakes and reservoirs in Iowa combined with their intensive recreational development make these two types of surface water sources largely inappropriate for agricultural usage irrespective of their water quality. Small ponds, on the other hand, are widely used for livestock watering. However, most of these are artificial and drain small, private catchments; and their quality as a water resource would have to be determined on a case by case basis.

The rivers and streams of Iowa are available nearly throughout their length for some type of agricultural usage, but in most cases, they serve only for direct watering of pasturing animals. The tremendous alterations in quality which can occur in a river in a very short time do not make them a highly desirable source of livestock water.

The quality of surface water in general is closely associated with seasonal changes and rainfall is probably the most important natural source of change. A heavy storm can alter the chemical nature of a river tremendously due to the sediment carried in surface runoff. Major changes occur in levels of suspended particles and associated substances such as pesticides, bacteria, nutrients and heavy metals.

During non-runoff periods, natural populations of algae and bacteria may alter surface water quality tremendously even to the extent of producing toxic compounds. While in the winter, the presence of ice-cover may result in de-oxygenation and the accumulation of harmful substances such as ammonia.

The utilization of surface water sources is further complicated by the presence of point-source discharges of wastewater. Even when highly treated, these municipal and industrial effluents can seriously degrade the quality of a stream especially during low stream flow periods.

In spite of these problems, the quality of water in most Iowa streams is generally good throughout most of the year. Unfortunately as with the bedrock aquifers, this quality is generally higher in eastern Iowa and especially in the northeast. The quality of the rivers in western Iowa is somewhat lower and usually subject to greater variations in quality and volume of flow.

Also in relation to ground water sources, it should be noted that surface waters in Iowa do carry a rather small dissolved mineral content as compared to many bedrock aquifers. The total dissolved solids concentration of most Iowa streams is rarely above 300 mg/l while in some wells it may be above 10,000 mg/l.

Water for Livestock Enterprises

Domestic animals represent an important segment of agriculture and are a vital source of food. Like man and many other life forms, they are affected by pollutants in their environment. In terms of evaluating our water resources as they apply to the livestock enterprises, it is thus essential to describe the following factors affecting livestock water quality: excess salinity, toxic elements and ions, biologically produced toxins, radionuclides, pesticide residues, and pathogenic and parasitic organisms.

It is well known that excessively saline waters can cause physiological upset or death of livestock. Problems of salinity are most severe in arid and semiarid regions where use of highly saline waters may be necessary, but it is also an important consideration in areas utilizing heavily mineralized ground water sources. It has been recommended that from the standpoint of salinity and its osmotic effects, water containing 3000 mg/l of soluble salts or less should be satisfactory for livestock under almost any circumstances.

In addition, there are many dissolved or suspended substances in water that may be toxic to livestock and the State of Iowa has no specific set of standards which governs the content of these substances in livestock water. The Federal EPA has, however, set down recommendations for upper limits of these substances in livestock water, some of which incorporate standards for human consumption.

Obviously any such recommendation about toxic substances is a compromise which cannot be said to protect every organism in every circumstance. However the recommended levels do allow a quantitative means of evaluating the usability of a water resource for livestock enterprises. I have listed the recommendations as follows:

Substance	Upper Limit
Aluminum	5 mg/l
Arsenic	0.2 mg/l
Cadmium	50 Hg/l
Chromium	1.0 mg/l
Cobalt	1.0 mg/l
Copper	0.5 mg/l
Fluoride	2.0 mg/l
Lead	0.1 mg/l
Mercury	10 Hg/l
Nitrate plus Nitrite Nitrogen	100 ppm
Nitrite Nitrogen	10 ppm
Selenium	0.05 mg/l
Vanadium	0.1 mg/l
Zinc	25 mg/l
Radionuclides	Use Fed. Drinking Water Stds.
Pesticides	Recomm. of Panel of Public Water Supplies

In addition, one must also consider iron and manganese which are not usually harmful, but which even at a few mg/l can cause clogging of lines to stock watering equipment or an undersirable staining and deposit on the equipment itself.

Also, there are biological agents which can cause contamination of water resources. The use of waters bearing heavy growths of blue-green algae should be avoided, as several species are capable of producing animal toxins.

It is furthermore essential that stock be kept from contaminated water or water that has not been adequately oxygenated because of pathogens and parasitic organisms which may inhabit such waters. One of the most significant factors in the spread of infectious diseases of domesticated animals is the quality of the water which they consume.

Data from our laboratory indicate that for the most part, background levels of the substances listed above are well below recommended maxima in both surface and ground waters in Iowa. Obviously there are exceptions. Several bedrock aquifers are objectionably mineralized, and some have shown excessive radiation. Surficial aquifers and especially surface waters seasonally exhibit contamination from bacteria, algae, and heavy metals.

In summation, it appears that ground water sources, especially bedrock aquifers, generally provide a more dependable supply and are less variable in composition than surface water sources. Due to regional variations, many livestock enterprises may not have access to an acceptable subsurface supply. It is here that compromises must be made. Either an alternate supply of acceptable quality but lower dependability must be utilized, or the individual must resort to water supply treatment methods. This then is an appropriate point of departure. The treatment and improvement of our water resources are the disciplines of our other panel members.

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PHYSICAL AND CHEMICAL MEANS OF IMPROVING WATER QUALITY

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PHYSICAL AND CHEMICAL MEANS OF IMPROVING WATER QUALITY

INTRODUCTION

All animals require water. The water content of animal bodies is relatively constant -- 68 to 72 percent of the total body weight on a fat-free basis. In the use of water to maintain this water content, animals -- like man and other life forms -- are affected by the pollutants in the water. These include all the pollutants that are also of concern to man and his use of water -- the presence of ions causing excessive alkalinity, elements and ions which are toxic, biologically produced toxins, radionuclides, pesticide residues, and pathogenic and parasitic organisms.

In considering water quality, it is well to remember that man can neither create nor destroy matter. All that man -- or nature -- can do is to change the form, the location, and the concentration of the various chemical elements in the environment. Thus, in discussing water quality and in evaluating the methods which are required to meet that water quality, we must be concerned with the concentration and form of the various constituents in water that are of primary concern. The constituents in water which may affect water quality may be grouped in several general classifications:

- Those constituents which are not permissible in water, i.e. toxic substances.
- Those constituents which are undesirable or objectionable, i.e. high mineral content.
- Those constituents which are permissible but not necessarily desirable, i.e. the presence of ions such as chloride.

- Those constituents which are desirable in water, i.e. a residual of disinfecting chemical to maintain the safety of water.

The classification of a particular constituent in water into one of the above groups will depend on the ultimate use of the water. The U.S. Environmental Protection Agency has established or is considering the establishment of many different water quality standards:

- Standards for surface waters to protect its recreational use.
- Standards for surface waters to protect cold and/or warm water fish.
- Standards for drinking water.
- Standards for water used in hemodialysis.
- Standards for water used in animal production?

Historically, the U.S. has maintained a single distribution system in a community and the old U.S. Public Health Service Drinking Water Standards (and the new U.S. Environmental Protection Agency Interim Drinking Water Standards which become effective in June, 1977) have been used as a basis for specifying the minimum water treatment to be provided. At the present time, the water supply industry is reevaluating the feasibility of establishing dual water systems in our communities:

- One system to deliver a drinking water supply (say 5 gallons per capita daily).
- One system to deliver a lesser quality of water for washing, bathing, stool flushing, lawn watering, etc. (say 100-150 gallons per capita daily).

The real impetus for such studies lies in the belief that some of the present needs to improve water quality will increase costs so significantly that it will be more economical to have a dual system and two water qualities than to treat the single system water to drinking water quality.

The major drinking water treatment problems at present are concerned with developing technology for:

- removal of particulates that may be involved in the incidence of human cancer, i.e. asbestiform fibers.
- developing methods of disinfecting water that will not result in formation of carcinogenic materials, i.e. chlorination of natural waters containing organics with resultant formation of chloroform and/or carbon tetrachloride.
- developing methods for the identification and evaluation of the public health significance of soluble organics which are present in all surface and many ground waters receiving domestic and industrial water discharges.

At present, the public health significance of these "supposed" problems is still being evaluated by hundreds of researchers in government, in industry, and in our universities.

QUALITY OF WATER FOR LIVESTOCK

Table 1 lists the maximum contaminant level in the EPA drinking water interim standard which becomes effective in June, 1977. This standard is based on the human ingestion of two liters of water per day. This is the current standard of drinking water quality which will control the design and treatment goal of all municipal water treatment systems. In addition, most communities will continue to meet the additional non-health related criteria contained in the U.S. Public Health Service Drinking Water Standards that are not included in the new EPA health-related new interim standards in Table 1. These include the items listed in Table 2.

In 1972, the Committee on Water Quality Criteria of the Environmental Studies Board (National Academy of Sciences and National Academy of Engineering) issued a report on "Water Quality Criteria, 1972" which included (Section V - Agricultural Uses of Water) recommended limits on toxic substances, pesticides, and pathogens and parasitic organisms in livestock waters. Until such standards are finally adopted, however, most waters used for human and animal use will be expected to meet the standards listed in Tables 1 and 2.

Table 1. EPA Interim Standards for Drinking Water
(All values represent maximum contaminant level in mg/l)

INORGANIC CHEMICALS		
Arsenic	0.05	
Barium	1.0	
Cadmium	0.01	
Chromium	0.05	
Fluoride	1.4 - 2.4	(depends on annual average maximum daily temperature)
Lead	0.05	
Mercury	0.002	
Nitrate, as N	10.0	
Selenium	0.01	
Silver	0.05	
ORGANIC CHEMICALS		
Endrin	0.0002	
Lindane	0.004	
Methorychlor	0.1	
Toxaphene	0.005	
Herbicides		
2,4D	0.1	
2,4,5-TP,(Silvex)	0.01	
PHYSICAL PARAMETERS		
Turbidity, TU	1	(up to 5 allowable under certain circumstances)
RADIOLOGICAL FACTORS		
Radium 226, pc/l	5	(combined radium 226 and 228)
Gross alpha, pc/l	15	
BACTERIOLOGICAL		
Coliform organisms/100 ml	1	

Table 2. Non-health related items in U.S. Public Health Service Drinking Water Standards not included in the health-related EPA Interim Standards

INORGANIC CHEMICALS	MAXIMUM CONCENTRATION	
Chloride	250* mg/l	(*recommended only)
Copper	1.0* mg/l	
Cyanide	0.01*, o.2 mg/l (mandatory)	
Iron	0.3 mg/l	
Manganese	0.05* mg/l	
Sulfate	250*	
Zinc	5*	
Total Dissolved Solids	500*	
ORGANIC CHEMICALS		
Carbon-Chloroform-Extract	0.2*	
Foaming agents, MBAS	0.5*	
PHYSICAL PARAMETERS		
Color, units	15*	
Threshold Odor	3*	
RADIOLOGICAL FACTORS		
Gross beta, pc/l	1000*	

TREATMENT METHODS

The actual type and degree of treatment required to meet the pertinent water quality standard will depend to a large extent on the source and quality of the raw or untreated water. Ground sources will usually contain large amounts of dissolved gases and minerals. They will normally contain considerable iron, hardness, and dissolved hydrogen sulfide, and be devoid or deficient in dissolved oxygen and devoid of suspended solids. In farming areas where heavy applications of fertilizer are practical, the ground waters may contain excessive concentrations of nitrates. Bacteriologically, such waters are usually satisfactory without treatment for disinfection if properly handled.

Surface water supplies from farm ponds, streams or lakes, on the other hand, normally contain large amounts of suspended solids, dissolved oxygen, and biological life, but may contain lower amounts of total dissolved minerals and hardness.

Numerous methods are used to prepare or treat water supplies for their intended use. In general, treatments which are provided fall into one of the following categories:

- removal of dissolved gases
- removal or conversion of dissolved minerals
- removal of suspended solids
- destruction of pathogens and other organisms
- stabilization of the water.

Iowa farm water supplies are usually derived from shallow wells, deep wells, or farm ponds, depending on which part of the state the water source is located. Shallow well waters are usually characterized by the following contaminants:

1. Little dissolved gas.
2. Significant iron (and perhaps manganese) concentrations (1-10 ppm, or pounds per million pounds of water).
3. High hardness due to presence of calcium and magnesium compounds (200-600 ppm).
4. Nitrate-Nitrogen concentrations close to or exceeding drinking standards.
5. Detectable concentrations of organic compounds resulting from pesticide or herbicide applications to farm fields.
6. Coliform bacteria levels which render the water unsatisfactory or unsafe for human consumption.

Deep well water supplies are usually characterized by the following contaminant conditions:

1. Significant quantities of dissolved gases such as methane, carbon dioxide, and hydrogen sulfide.
2. Significant iron (and perhaps manganese) concentrations (1 to 10 ppm).
3. High hardness.
4. Low nitrate-nitrogen concentrations.
5. Low levels of organic contaminants.
6. Safe levels of coliform bacteria.

Surface waters such as runoff water stored in farm ponds are usually characterized by the following contaminant conditions:

1. Variable, but high levels of suspended matter consisting of algal cells, soil particles, and so forth (High water turbidity).
2. Low iron and manganese concentrations.

3. Low levels of nitrate-nitrogen, but with possibility of high levels during spring runoff periods.
4. Relatively high concentrations of organic herbicides and pesticides applied to fields in the area draining to the farm pond.
5. Very high concentrations of coliform bacteria -- and frequently pathogenic organisms -- in the water runoff from fields in which animals are housed or pastured.

Removal of Dissolved Gases

Well waters often contain dissolved gases such as methane, carbon dioxide, and hydrogen sulfide. These gases are dissolved in water much like carbon dioxide is dissolved in a bottle of coke. If the water is exposed to the atmosphere at ground level, the water pressure is reduced and the gases will be released and escape. To accelerate the escape, spray aerators or injection of compressed air into the water are used. The primary purpose of such aeration is to facilitate the escape of the gases in the water and to enhance the solubility of oxygen into the water.

Removal of Dissolved Minerals

Chemical Precipitation

Some minerals are soluble in water in the absence of free oxygen but become unstable when exposed to the air. For example, iron and manganese are frequently found in solution in well water, usually in the form of a soluble bicarbonate. When exposed in oxygen dissolved in water, they will be oxidized to form an insoluble precipitate. This precipitate can then be removed along with other types of suspended matter. The chemical reaction can be represented by:

$$\mathrm{Fe^{++}}\text{ (ferrous) + oxygen} \longrightarrow \mathrm{FeOx}\text{ (ferric oxide)}$$

Soluble Iron — Insoluble Iron

The reaction may require a substantial holding time (10-60 min.) for completion. If the water is not exposed to soluble oxygen, the iron or manganese can be oxidized by the addition of either chlorine or potassium permanganate:

$$\mathrm{Fe^{++} + Mn^{++}} + \text{oxygen} + \mathrm{Cl_2} \longrightarrow \mathrm{FeOx}\downarrow + \mathrm{MnO_2}\downarrow$$

Soluble ions — Insoluble ions

$$\mathrm{Fe(HCO_3)} + \mathrm{KMnO_4} \longrightarrow \mathrm{Fe(OH)_3}\downarrow + \mathrm{MnO_2}\downarrow$$

Ferrous bicarbonate	Potassium Permanganate	Ferric Hydroxide	Manganic Oxide

Effective suspended solids removal is essential after chemical oxidation, since the flocculent metal oxides are not large or heavy enough to settle by gravity.

Manganese zeolite is a natural synthetic resin coated with manganese dioxide that reacts with soluble iron and manganese removing them from solution and retaining them in the zeolite bed. After the zeolite is saturated with metal ions, the media is backwashed and regenerated with potassium permanganate.

The minerals which cause hardness (Calcium and magnesium) are not affected by aeration or by addition of oxidants such as chlorine or permanganate. They can, however, be removed by conversion to insoluble precipitates by the addition of lime and/or soda ash:

Lime reaction

$$\mathrm{Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O}$$

Soluble hardness — Precipitated hardness

Soda ash reaction

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$$

Soluble hardness		Precipitated hardness	Soluble compound

Following precipitation, the water must be filtered to remove the precipitated compounds. The precipitation-filtration of hardness is not a common practice in farm water supply service.

Ion Exchange

Soluble minerals in water can also be removed by an ion-exchange process. For example, Figure 1a shows a bar graph of the mineral content of a typical well water. In the zeolite process, the water is passed through a tank of ion-exchange mineral where the zeolite exchanges its sodium for the calcium and magnesium in the water:

$$Na_2Z + CaSO_4 \longrightarrow CaZ + Na_2SO_4$$

Sodium Zeolite	Soluble Hardness	Calcium Zeolite	Soluble Compound

The calcium stays in the tank and the sodium replaces it in the water, as shown in Figure 1b. When all the sodium in the zeolite is replaced, the zeolite is regenerated by running a sodium chloride (salt) solution through the tank to release the hardness cations and again convert the mineral to a sodium zeolite. This is the basis of the typical home water softener.

Destruction of Pathogens

Pathogens are bacteria which produce disease in man or animals. They can sometimes be removed from water by filtration, but are more commonly destroyed by chlorination. In municipal practice, a chlorine residual of 0.5 ppm of free chlorine will normally provide adequate water disinfection after 30 minutes of contact. The chemical reaction using chlorine gas is given by:

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$

Hypochlorous Acid
(the killing agent)

The HOCl will dissociate as follows:

$$HOCl \underset{pH<7}{\overset{pH>8}{\rightleftarrows}} H^+ + OCl^-$$

The HOCl and OCl^- are considered to be free chlorine residuals. Since the HOCl is the effective agent, disinfection takes place faster as low pH values.

If ammonia is present in water, a frequent case in farm wells, the chlorine will react to form chloramine compounds:

$HOCl + NH_3 \longrightarrow H_2O + NH_2Cl$ (mono-chloramine)

$HOCl + NH_2Cl \longrightarrow H_2O + NHCl_2$ (di-chloramine)

$HOCl + NHCl_2 \longrightarrow H_2O + NCl_3$ (tri-chloramine).

The chloramine compounds are disinfectants but under identical conditions require 10 to 40 times longer to produce the same degree of kill.

The effectiveness of chlorine disinfection is a function of:

- chlorine residual, mg/l
- type of residual (free or chloramine)
- the water temperature (higher the better)
- the chlorine demand of the water which may use up the chlorine
- the pH of the water (closer to pH of 7 or below the better)
- the type of organisms present.

Since farm wells water treatment practice cannot assure the maintenance of a constant level of residual and a long contact time, a form of overchlorination (Superchlorination) is used to give high residuals (5-10 mg/l) for short times (3-5 minutes) followed by dechlorination of the water by passing it through a carbon filter. Farm animals will avoid water containing 5-10 ppm chlorine residuals, but will drink it if no other water is available. Thus, superchlorinated water can be fed to animals without dechlorination. Dechlorinated water, however, would be desirable for human consumption.

Removal of Suspended Solids

All surface waters and some partially treated ground waters contain material in suspension. A number of different types of filters can be used effectively to remove such suspended matter from water. The selection of a "reasonable" filter for a given installation will depend primarily on first cost and the operating requirements of the filters. Some potential choices include:

1. Slow sand filters -- A layer of 24-36 inches of ungraded 0.50-0.60 mm sand through which <u>untreated</u> water is filtered at a rate of 2-4 million gallons per acre per day. Service is required for cleaning the filter every 4-6 months. In the late 1950's, many farm ponds were supplied with in-bank slow sand filters that could not be properly cleaned.
2. Rapid sand or rapid dual media filters -- A 24-36 inch layer of 0.5-0.6 mm sand or a layer of such sand under a layer of 1.0-1.2 mm coal (or 3 or 4 media) through which chemically pretreated (alum or polymer) water is filtered at a rate of 125-500 million gallons per acre per day. Service is required at not less than weekly intervals, but filter size is greatly reduced.

3. Diatomite filters in which a thin layer (1/8") of diatomite and/or activated carbon is deposited on a supporting medium and through which water is filtered at a rate of 0.1 to 1.0 gpm per sq. ft. This filter permits use of large filter areas in small tank volumes and provides long times between periods of required service.
4. Cartridge filters.

TYPICAL RURAL WATER SYSTEMS

In order to simplify discussion, the typical rural water treatment systems might consist of the following:

<u>System 1</u> Chlorinator, for adding chlorine for iron or manganese oxidation.

Contact Tank, for providing disinfection contact time.

Diatomite-Carbon Precoat Filter, for removal of chlorine and suspended solids from total flow.

or a

Dual Media Filter, for removal of suspended solids <u>and</u>

Carbon Filters, for removal of chlorine, organics, tastes and odors from drinking water.

Zeolite Softeners, for hardness reduction.

<u>System 2</u> Manganese Greensand filter, for removal of iron and manganese.

Zeolite softener, for removal of hardness.

Chlorinator, for disinfection.

Contact Tank, for contact time.

Carbon Filter, for removal of residual chlorine, organics, tastes and odors.

These systems should provide satisfactory water quality for animal production at reasonable cost.

RECENT DEVELOPMENTS

Membrane Units

In recent years, attention has been focused on development of methods for complete demineralization of water. In other words, to remove all of the cations and anions in water, as shown in Figure 1c, so as to produce a mineral-free water. In other words, the objective is to replace all the cations with H^+ or hydrogen and all the anions with OH^-. Technically, this can be accomplished today by ion exchange, electrodialysis, or reverse osmosis. Electrodialysis employs an induced electrical current to isolate the positive and negative ions in solution by means of selective membranes that permit ions to pass through the material from the diluted solution on one side to the concentrated solution on the other.

Reverse osmosis involves the forcing of water through a membrane against the natural osmotic pressure to accomplish separation of water and ions. Culligan, USA has developed a series of reverse osmosis units for rural water treatment that provide for effective operation at reasonable -- though high -- cost. The pressure required may be several hundred psi. Membrane treatments such as electrodialysis and R.O. include chemical precipitation of salts with low solubility and membrane clogging as a result of suspended colloidal matter. The units will probably not find universal application in water treatment because of their costs. A typical R.O. unit containing hollow fiber membranes (5.5 in. diameter, 47 in. long) will contain 1500 sq. ft. of fiber and, operating at 400 psi operating pressure, will produce about 2000 gallons of product water per day.

Specific cation-anion exchange units

In recent years, attention has been directed to the development of treatment units to remove a particular cation and/or anion. In wastewater treatment, for example, clinoptilolite is an ion exchange material that will remove ammonia from wastewaters.

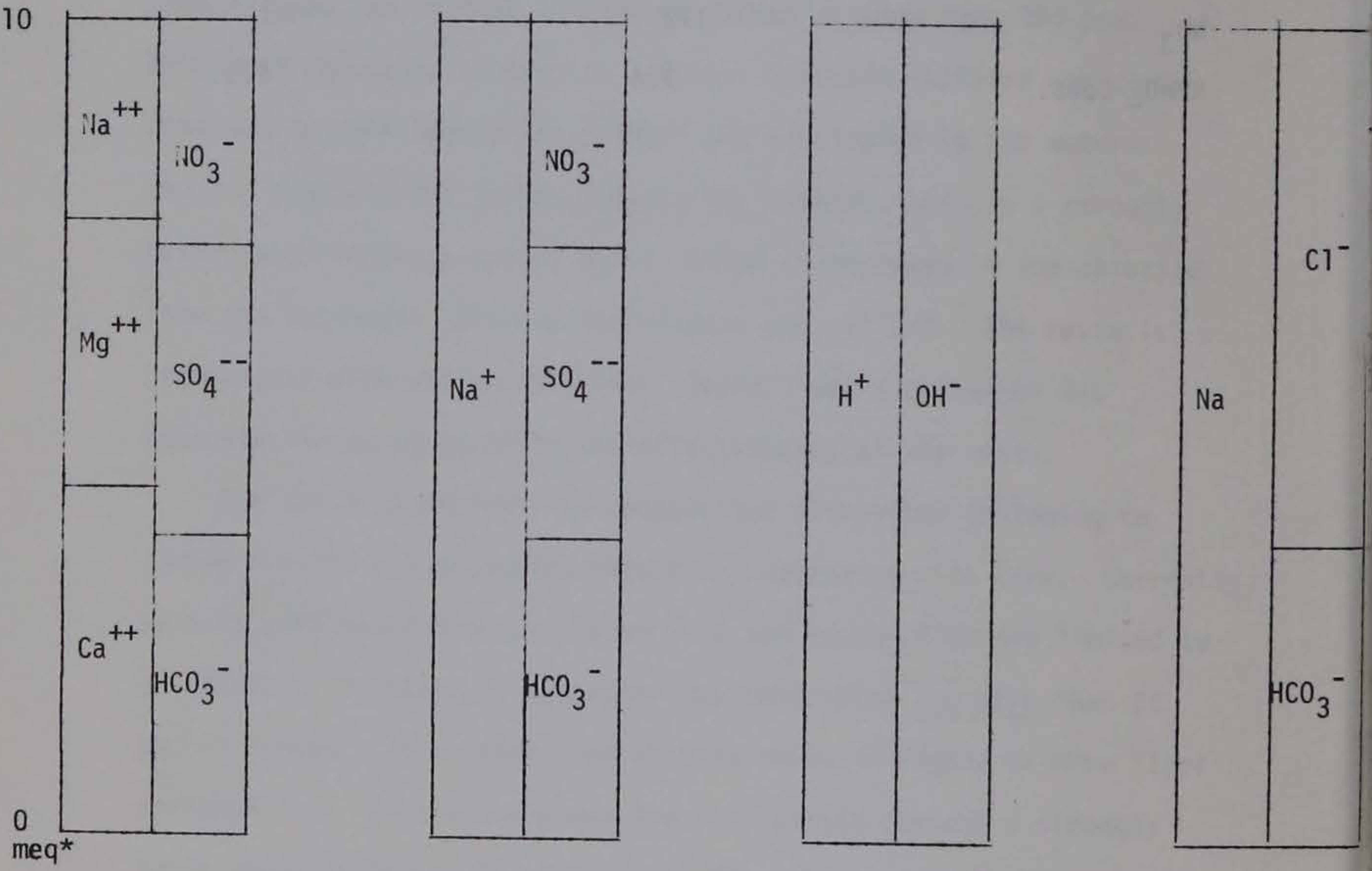
In water supply work, attention has been directed to removal of nitrate-nitrogen when it is present in concentrations greater than 10 ppm, and sulfate in concentrations greater than 250 ppm. Nitrate-N can cause disease in infants, and high sulfates can cause diarrhea in most people and animals not acclimated to the water. The X-L Laboratories in Des Moines, for example, markets a strongly basic anion exchange resin, ASB-1, which is employed in the chloride form and exchanges chloride for nitrate and sulfate. The resin is regenerated with sodium chloride. Table 3 was supplied by X-L Laboratories to demonstrate the effectiveness of the resin.

The use of such resin in conjunction with water softening to remove calcium and magnesium should be undertaken with care. Currently, persons with heart disease placed on a low sodium diet are limited to an intake of 2 liters of water per day containing <u>not</u> <u>more</u> than 23 ppm of sodium. If a water such as that shown in Figure 1a were first softened in a zeolite exchanger and then passed through a strongly basic anion exchanger for removal of the nitrate, the finished water would have the mineral content shown in Figure 1d. Not only would the water have an extremely high sodium content such that it could not be consumed by low-sodium dieters, but the high chloride level could produce a "salty" tasting water.

Table 3. Removal of Sulfate and Nitrate by a strongly basic anion exchange resin.

	Raw Water	Treated Water
Total Alkalinity, ppm	155	108
Free CO_2 (as $CaCO_3$)	39	13
Cl	147	330
SO_4	61	0
NO_3	172	1
$KMnO_4$ Cons.	7.4	4.9

Figure 1: Mineral content of typical well waters before and after different ion-exchange treatments.



a) Raw Water

b) Zeolite softening

c) Mineral free water

d) Zeolite softening NO$_3^-$ and S
Removal.

* milliequivalents per liter

DETERMINATION OF WATER QUALITY FOR ANIMALS

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The 1968 Water Resources Council estimated that 1.7 billion gallons of water were required per day by the livestock in the United States. Sixty-percent of this water came from wells with the rest originating in streams, lakes, springs, and impoundments. With such a massive volume of water involved in the livestock industry, it is not difficult to appreciate that many different chemicals and substances could be associated with water and in turn affect its quality.

Increased physical concentrations of both livestock and poultry, combined with heightened emphasis on nutrition and health, have raised the number of inquiries about water quality. The safety factor of water has become a greater concern as the chances of pollution by the public, industry, and agriculture itself increase.

Dissolved substances in sufficient concentration in the drinking water do affect livestock. Considerable research on such matters has been done, and more is now underway. Several factors, including the form in which the substance is ingested, the level of other substances in the water, the pH of the water, and the age of the animal are known to modify the effect of a given concentration of a given substance in the water. The outcome of the individual researches now in progress will make possible a clearer definition of water-quality effects than is available at present.

There are three basic concerns about the quality of water for livestock. First, is the quality of the water poor enough to affect the performance of the livestock? Second, does the water serve as a carrier to spread disease throughout the livestock population? Third, does the quality of the water affect the acceptability or safety of animal products for human consumption?

The individual producer is vitally interested in the performance of his livestock, the control of disease within his flocks or herds, and the acceptability of his livestock products. These factors affect the economics of his operation, and he must be alert to them to stay in business.

It is well known that certain livestock diseases are transmitted locally through the drinking water but that widespread transmission of diseases is by transportation of livestock, not water.

There are few toxicities to livestock from intestion of natural constituents in the drinking water, and hazards to the human population from animal products containing residues of drinking-water constituents are even fewer or nonexistent. The explanation for the comparative safety of animal products for human consumption despite the intake of various quantities of dissolved substances by the animals in their drinking water lies in certain physiological features that are common to the various classes of livestock. Animals are naturally protected against overdoses of most solutes in the water they drink by five mechanisms, namely, reduced intake of water, decreased rate of absorption of solutes, increased rate of excretion of solutes, adaptation to the constituent or constituents in excess, and storage of the constituent in less metabolically active sites and/or nonedible tissue such as bone.

It has been readily apparent to livestock producers, animal scientists, and veterinarians that quality standards proposed for human water supplies were at best impractical and uneconomical for livestock and poultry water supplies. To fill this void of water quality standards aimed specifically at livestock, the National Academy of Sciences published "Nutrients and Toxic Substances in Water for Livestock and Poultry" in 1974. In addition, the Council for Agricultural Science and Technology (Cast, 1974) scientifically documented its ideas on livestock water standards by answering preliminary "Proposed Water Quality Standards" offered up by the U.S. Environmental Protection Agency in 1973. Many of the limits of concentration of specific substances proposed by these groups are presented in Table 1.

This paper draws heavily on the logic and comments of the above-mentioned committee's efforts.

The methods employed in determining the specific quality parameters of water are quite important. Not only must a specific method or technique be reproducibly accurate within a particular laboratory but should also be standardized between laboratories so that the results of two different facilities can be compared to each other for meaningful interpretation.

TABLE 1 RECOMMENDED LIMITS OF CONCENTRATION OF SOME POTENTIALLY TOXIC SUBSTANCES IN DRINKING WATER FOR LIVESTOCK AND POULTRY

	Safe Upper Limit of Concentration (mg/l)		
Substance	U.S. EPA[a] (for Humans)	NAS[b]	Cast[c]
Arsenic	0.05	0.2	0.5
Barium	1.0	Not Established	
Boron			5.0
Cadmium	0.01	0.05	0.5
Chromium	0.05	1.0	5.0
Cobalt		1.0	1.0
Copper		0.5	0.5
Fluoride		2.0	3.0
Iron		Not Established	No Limit[d]
Lead	0.05	0.1	0.1
Manganese		Not Established	No Limit
Mercury	0.002	0.01	0.01
Molybdenum		Not Established	No Limit
Nickel		1.0	
Nitrate-N	10	100	300
Nitrite-N		10	10
Salinity		See Table 2	
Vanadium		0.1	1.0
Zinc		25.0	25.0

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a - according to U.S. Environmental Protection Agency, Interim Primary Drinking Water Standards. Fed. Reg. 40 (51): 11990, March 14, 1975.

b - recommended by National Academy of Sciences publication Nutrients and Toxic Substances in Water for Livestock and Poultry.

c - recommended by the Council for Agricultural Science and Technology, Report No. 26, Quality of Water for Livestock.

d - no limit: experimental data available are not sufficient to make definite recommendations.

The specific methods used and standardized between laboratories have been documented in "Standard Methods for the Examination of Water and Waste Water" (APHA, 1975) and in "Methods for Chemical Analysis of Water and Waste Water" (U.S. Environmental Protection Agency, 1974, Office of Technology Transfer, Washington, D.C.).

Some chemical determinations for assessing water quality, such as nitrates in water, are available in an attractively inexpensive field-test kit form. Though these kits have a fair degree of reliability, they should be used only as a guide and should be substantiated by more sophisticated laboratory techniques.

Various methods are used in the literature and by different laboratories for expressing the concentration of substances in water. These include parts per million (ppm), micrograms per milliliter (ug/ml), and milligrams per liter (mg/l). For all practical purposes, these expressions are equivalent.

MICROBIOLOGIC STANDARDS:

Microbiologic examination of water samples determine the sanitary quality and suitability for general use. These examinations are intended to indicate the degree of contamination of water with wastes from human or animal sources.

Traditionally, laboratory tests for the detection of indicator organisms, rather than of pathogens, have been used. The coliform group of bacteria has been the principal indicator of the suitability of a particular water supply. Experience has established the significance of coliform group densities as criteria of the degree of pollution and thus the sanitary quality of the sample under examination.

It has become the custom to report the results of the water coliform test by the multiple-tube fermentation procedure as a Most Probable Number (MPN) index. It should be realized that this is merely an index of the number of coliform bacteria that, more probably than any other number, would give the results shown by the laboratory examination. It is not an actual enumeration of the coliform bacteria. By contrast, direct plating methods such as the membrane filter procedure permit a direct count of coliform colonies. In both procedures coliform density is reported conventionally as the MPN or membrane filter count per 100 ml. The methods of these techniques are well described (APHA, etal 1975). Recent advances in microbiologic examination of water include the detection of fecal estreptococci as indicators of significant fecal pollution. In addition, the differentiation of fecal coliforms as a subgroup in the general category of coliforms is quite encouraging. By detecting coliforms from the gut and feces of warm blooded animals much information will be gained concerning the possible source of water pollution. The U.S. EPA Drinking Water Standards set an action limit of 4 or more coliform colonies per 100 ml of water.

The standard plate count, which enumerates the number of bacteria multiplying at 35^{O}C, may yield useful information about the quality of the water and may provide supporting data on the significance of coliform test results. This procedure may also be useful in judging the efficiency in operation of various water treatment processes. The U.S. EPA action limit is 500 organisms/ml.

EPA acceptable limitations for water to be used directly by livestock should not exceed 5000 coliforms per 100 ml. The monthly arithmetic density of fecal coliforms should not exceed 1000 per 100 ml. EPA said both limits should be an average of at least two consecutive samples examined per month and any one sample examined in any one month should not excceed a total coliform count of 20,000 per 100 ml. or a fecal coliform density of 4000 per 100 ml.

CAST (1974) responded to the EPA by stating that coliform bacteria are ubiquitous, often occurring in much higher numbers than the maximum values in the EPA (1974) document. These organisms generally are nonpathogenic. As long as animals are allowed to range and drink surface waters, the proposed limits are unenforceable and of doubtful value.

CAST also noted that considerable experimental work has been done in recent years on refeeding animal wastes. This practice subjects the animals to far greater numbers of coliform bacteria than would be ingested in water containing the maximum numbers of such bacteria mentioned in "Proposed Criteria for Water Quality." There seems to be some question about the real value of refeeding animal wastes, but the animals don't seem to mind it. The Food and Drug Administration is now said to be readying proposed regulations that set forth the conditions under which animal wastes may be refed. Because the difference between ingestion of a given number of coliform bacteria in drinking water and in more or less solid wastes if of no real concern as regards effects, it would seem that "no limit" would represent a more realistic tolerance than the one proposed by EPA.

SALINITY:

Salinity is defined as the total solids in water after all carbonates have been converted to oxides, all bromide and iodide have been replaced by chloride, and all organic matter has been oxidized (APHA etal, 1975). In more general terms, salinity is an expression of the amount of dissolved salts in a particular water sample. It has long been known that animals or humans restricted to waters with high salt content may suffer physiologic upset or death. The ions most commonly involved in highly saline waters are calcium, magnesium, sodium, bicarbonate, chloride, and sulfate.

Water "hardness" has been understood to indicate the tendency of water to precipitate soap or form scale on heated surfaces. Hardness is generally expressed as the sum of calcium and magnesium reported in equivalent amounts of calcium carbonate. Other cations, such as strontium, iron, aluminum, zinc, and manganese, also contribute to hardness, and when present in unusual amounts should be determined and included in the computation.

Hardness is sometimes confused with salinity, but the two are not necessarily correlative. Waters containing high levels of sodium salts and therefore having high salinity can be very soft if they contain low levels of calcium and magnesium. Most ground waters generally have hardness values of less than 2000 mg/l, but in some arid regions these values may be higher.

The hardness of domestic water, according to Durfor and Becker (1964), may be classified as:

Hardness Range (mg/l)	Description
0-60	Soft
61-120	Moderately hard
121-180	Hard
> 180	Very hard

Hardness is sometimes reported as grains per gallon. (1 grain per gallon is equivalent to 17.1 mg/l.) Hardness in itself is not a problem in livestock drinking water.

The amount of dissolved salts in a water sample is in some cases expressed in terms of conductivity. Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This number depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The units of conductivity are mhos usually over a certain distance such as a centimeter. Freshly distilled water has a conductivity of 0.5 to 2 umhos/cm. The conductivity of potable waters in the United States ranges generally from 50 to 1,500 umhos/cm. The concentration (in mg/l) of dissolved ionic matter in a sample often may be estimated by multiplying the conductivity (in umhos/cm) by an empirical factor. This factor may vary from 0.55 to 0.9, depending on the soluable components of the water and on the temperature (APHA, etal, 1975).

The general recommendations for the use of saline waters for livestock and poultry are presented in Table 2.

Livestock tolerate drinking water with a content of dissolved salts at least as great as 10,000 mg/l, generally with no more apparent effects than mild diarrhea. The upper limit of 3,000 mg/l recommended by some was offered in the sense of a desirable value from the standpoint of the physiology of the animals. One must distinguish clearly between such a value and the value of 10,000 mg/l that we suggest from the standpoint of economics of production. (Safety of the products to the consumer is not impaired in either case.) If the maximum permissible limit were to be set below 10,000 mg/l, some areas where livestock are now raised would be closed to this enterprise.

A number of elements found in water seldom offer any problem to livestock because they do not occur at high levels in soluable form or because they are toxic only in excessive concentrations. Examples of these are iron, aluminum, beryllium, boron, chromium, cobalt, copper, iodide, manganese, molybdenum and zinc. Also these elements do not seem to accumulate in meat, milk, or eggs to the extent that they would constitute a problem in livestock drinking waters under any but the most unusual conditions.

TABLE 2 A GUIDE TO THE USE OF SALINE WATERS FOR LIVESTOCK AND POULTRY

Total Soluble Salts Content of Waters (mg/liter)	Comment
Less than 1,000	These waters have a relatively low level of salinity and should present no serious burden to any class of livestock or poultry.
1,000-2,999	These waters should be satisfactory for all classes of livestock and poultry. They may cause temporary and mild diarrhea in livestock not accustomed to them or watery droppings in poultry (especially at the higher levels), but should not affect their health or performance.
3,000-4,999	These waters should be satisfactory for livestock, although they might very possibly cause temporary diarrhea or be refused at first by animals not accustomed to them. They are poor waters for poultry, often causing watery feces and (at the higher levels of salinity) increased mortality and decreased growth, especially in turkeys.
5,000-6,999	These waters can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. It may be well to avoid the use of those approaching the higher levels for pregnant or lactating animals. They are not acceptable waters for poultry, almost always causing some type of problem, especially near the upper limit, where reduced growth and production or increased mortality will probably occur.
7,000-10,000	These waters are unfit for poultry and probably for swine. Considerable risk may exist in using them for pregnant or lactating cows, horses, sheep, the young of these species, or for any animals subjected to heavy heat stress or water loss. In general, their use should be avoided, although older ruminants, horses, and even poultry and swine may subsist on them for long periods of time under conditions of low stress.
More than 10,000	The risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

From: NAS, Nutrients and Toxic Substances in Water for Livestock

Therefore, CAST (1974) has recommended "no limit" in the maximum allowable concentration in livestock drinking water for many of these elements.

The following discussion briefly enumerates some of the substances in water that may be of potential concern.

ARSENIC

Experimental data from trials with arsenate and arsenite do not indicate toxicity or excess accumulation in the tissues until animals are exposed to concentrations much in excess of the 0.5 mg/l that CAST considers a more reasonable tolerance than the 0.2 mg/l suggested by the EPA.

CADMIUM

In ruminants, cadmium is poorly absorbed and therefore not concentrated in tissue under normal conditions. A tolerance level of 0.5 mg of cadmium per liter would seldom occur in water but would afford a tenfold safety factor even if it should occur.

COPPER

A concentration of 0.5 mg of copper per liter provides a safety margin even for sheep, which are more sensitive to copper than are other livestock. Water containing 0.5 mg of copper per liter supplies about 30% of the daily requirement of sheep for this element (Milne and Weswig, 1968).

FLUORINE

Fluorine present as fluoride at a concentration of 3 mg/l will cause fluorosis (mottling of teeth) but will result in teeth with less wear and fewer cavities than will a much lower concentration. There is little accumulation in soft tissues. A concentration of 3 mg of fluorine per liter is justified on the basis that water consumed by both the human and animal population in many areas exceeds this concentration without apparent detrimental effects other than fluorosis. In 1969, 245 known communities representing 500,000 persons were consuming water containing from 3.0 to more than 5 mg of fluorine present as fluoride per liter (Theuer, etal, 1971; NAS, 1971; Maier, 1972).

IRON

Under usual conditions, water supplies only a small percentage of the iron available to animals. Because iron from natural sources is absorbed with efficiency less than 10%, the iron in water should not pose a hazard to animals. Under these circumstances, the "no limit" recommendation is reasonable. High doses of the more available forms of iron, however, are toxic.

LEAD

Lead is an element that accumulates in animal tissues. Because of its toxicity, the concentration should be low in the water consumed by animals. The figure of 0.1 mg/l provides a reasonable margin of safety, to judge from the available information.

MERCURY

The NAS publication, "Water Quality Criteria, 1972," contains the estimate of 0.03 mg of mercury as methyl mercury per liter as being sufficient to increase the body burden of mercury in the animal body at infinite time to 0.5 ppm, which is the maximum allowable concentration in fish allowed at present for human consumption -- a figure that includes a factor of safety. Methyl mercury is more readily absorbed than inorganic forms of mercury. Methyl mercury is produced biologically in bottom sediments that contain considerable mercury. Waters used for drinking by livestock would rarely be of the type in which the mercury would be present almost exclusively in the form of mthyl mercury. In view of these facts, the figure of 0.001 mg/l proposed as a tolerance figure in the EPA document seems unduly low. The figure of 0.01 mg/l recommended in the NAS publication should still provide an ample margin of safety (Ammerman etal, 1973).

NITRATE/NITRITE

The nitrate ion (NO_3^-) is both a product and a reactant in the chain of animal and plant nitrogen metabolism. The nitrate ion can be reduced to form the nitrite ion (NO_2^-). Nitrate is utilized by plants to form plant protein which in turn is used to form animal protein. Decaying animal or plant protein, animal metabolic waste (urea and ammonia), nitrogen fertilizers, silage juices, and soil high in nitrogen -- fixing bacteria may be sources of nitrates and nitrites. Nitrates and nitrites are water soluable and thus if added to soil may be leached away moving with the ground water into the water table. The likelihood of high levels of nitrate contamination to a well or reservoir is much greater when the source of the nitrate is nearby. The most common source of contamination to wells is surface water runoff into shallow, poorly cased wells. Ponded water which collects feedlot or fertilizer runoff may contain toxic levels of nitrates

The nitrate ion itself is not particularly toxic. However, nitrite, the reduced form of nitrate, is readily absorbed and is quite toxic. Ruminants and herbivores can readily reduce nitrate to nitrite and toxicosis may occur. The nitrite ion oxidizes ferrous ion in hemoglobin to the ferric (trivalent) state forming methemaglobin which cannot accept molecular oxygen. The result is tissue hypoxia or anoxia due to poorly oxygenated blood.

Levels of nitrate in water may be expressed in a number of ways. Mg of nitrate per liter as well as mg of nitrate-nitrogen per liter have been frequently used. Each of these expression forms can be converted to the other designation (see Table 3). These distinctions must be remembered when evaluating laboratory data.

Acute nitrate poisoning in animals may be expected when nitrates exceed 1500 mg/l in the water or 1.0% nitrate (dry weight basis) in the forage (Buck,etal, 1976). Recent work (Dollahite and Rowe, 1974) indicates water containing 2,000 mg/l nitrate can be fed at 10 percent of body weight to cattle for as long as seventeen days with no indication of acute toxic effects. However, 3000 mg/l given to cattle for three days resulted in death from acute nitrate poisoning.

TABLE 3 NITRATE AND NITRITE EXPRESSIONS AND CONVERSION FACTORS FOR CONVERTING FROM ONE FORM OF EXPRESSION TO ANOTHER

FORM A	FORM B				
	N	NO_2	NO_3	KNO_3	$NaNO_3$
Nitrate-Nitrogen (N)	1.0	3.3	4.4	7.2	6.1
Nitrite-Nitrogen (N)	1.0	3.3	4.4	7.2	6.1
Nitrate (NO_3)	0.23	0.74	1.0	1.63	1.37
Nitrite (NO_2)	0.3	1.0	1.34	2.2	1.85
Pottassium Nitrate (KNO_3)	0.14	0.64	0.61	1.0	.84
Sodium Nitrate ($NaNO_3$)	0.16	0.54	0.72	1.2	1.0

To convert Form of Expression A to the equivalent amount of Form B, multiply A by the appropriate conversion factor.

(Form A X Conversion Factor = Form B)

Examples:
1. 1.0% nitrate-nitrogen X 4.4 = 4.4% nitrate
2. 1.0% nitrate X 0.23 = 0.23% nitrate nitrogen
3. 1.0% KNO_3 X 0.61 = 0.61% nitrate
4. 1.0% KNO_3 X 0.14 = 0.14% nitrate-nitrogen

The effects of feed and water nitrate levels are additive and both must therefore be considered when evaluating a potential nitrate problem.

The variation in susceptibility to nitrate toxicosis for different animals is also a consideration. Monogastric animals are generally quite tolerant to nitrate, there being no mechanism for rapid reduction to the more toxic nitrite. Nonruminants are approximately ten times more susceptible to oral nitrite than to nitrate, while ruminants are some two or three times more susceptible to nitrite than nitrate (Emerick, 1974).

The USPHS maximum limit for nitrate in water that is to be used for preparation of baby formulas is 45 mg/l. This limit is set to prevent the methemoglobin of "blue baby" syndrome in infants. It has been suggested that neonatal swine are also quite susceptible to elevated nitrates, but Emerick etal (1965) has concluded that pigs one week old are no more susceptible to nitrate poisoning than are older growing swine.

Reports of experimental reproduction of a chronic or low level nitrate poisoning syndrome in animals have been extensively reviewed (Turner and Kienholz, 1972; Emerick, 1974; Murdock, 1972; and Ridder and Oehme, 1974). The bulk of the evidence indicates that sublethal or chronic effects are extremely rare and difficult to varify. When present, the clinical signs usually reflect a lowered degree of acute toxicosis. Even in view of these findings, however, moderate levels of nitrate in water continue to be incriminated in several animal health problems. Among these are poor growth rate, abortion, infertility, Vitamin A deficiency, interference with iodine metabolism, and increased susceptibility to infection. Experimental evidence to substantiate many of these claims is lacking. Therefore, CAST (1974) concluded and recommended a tolerance of 300 mg of nitrate -- plus nitrite-nitrogen per liter (1300 mg nitrate/l) is consistent with recognized safe levels in feed. This level offers an adequate margin of safety even if ruminants were to consume their total daily water intake at one time. Nitrite is much more toxic than nitrate, however, and a tolerance of 10 mg of nitrate-nitrogen per liter (33 mg nitrite/l) is a reasonable figure for nitrite-nitrogen.

SELENIUM

Selenium is an essential element, and in many areas of the U.S. it is deficient in feeds and in surface water consumed by livestock. Deep well water in the same location may contain a higher level of selenium that would be beneficial to the livestock. Although some spring and irrigation waters contain more than 1 mg of selenium per liter, no substantiated cases of selenium poisoning in livestock by the selenium they ingest in drinking water have been reported. Moreover, we note that over a considerable part of the United States livestock ingest 0.5 ppm or more of naturally occurring selenium in their diets without apparent harm to them and without accumulation of levels of selenium in their tissues that would make the meat or other livestock products unsuitable for human consumption. In view of these facts, and the undesirable economic consequences of setting a tolerance below the concentration in some natural waters unless the waters have posed health hazards to livestock or to persons consuming products from the livestock, CAST considers that the proposed tolerance of 0.05 mg/l in the EPA document is unduly low. A figure of 0.1 mg/l is suggested as more reasonable. The suggested figure of 0.1 mg/l provides at least a tenfold safety margin even for the selenite form (Weeth, 1973; Squires, 1973; NAS, 1971b).

ZINC

Zinc is an essential element in animal nutrition. It has a low degree of toxicity, having been tolerated by swine in concentrations of 1000 ppm in the feed. It sometimes occurs in natural waters in concentrations as great as 50 mg/l. Because this level should be innocuous and would not unnecessarily label certain waters as unsuitable when there is no evidence that they are unsatisfactory, the level of 50 mg/l has more to recommend it from the practical standpoint than does the level of 25 mg/l.

PESTICIDES

Pesticides enter water from soil runoff, drift, rainfall, direct application, accidental spills, or faulty waste disposal techniques (Nicholson, 1970; Timmons etal, 1970). The subject of toxic levels of pesticides and herbicides in water for livestock and other agricultural uses was reviewed by Edwards (1970), Little (1970), and the National Academy of Science - National Academy of Engineering (1972). In general, there is not sufficient data available when considering the great number of chemical pesticides, the variability of species response, and the great dilution factors usually present to make hard and fast recommendations on allowable limits for livestock waters.

The U.S. EPA (1975) has recommended that the following maximum allowable concentrations of pesticides not be exceeded in human drinking water:

Pesticide	Maximum Concentration (mg/l)
Aldrin	.001
DDT	.05
Dieldrin	.001
Chlordane	.003
Endrin	.0002
Heptachlor	.0001
Heptachlor Epoxide	.0001
Lindane	.004
Methoxychlor	.1
Toxaphene	.005
2,4-D	.1
2,4,5-T	.01

The U.S. EPA states the data is insufficient at this time to establish limits of the organophosphorus insecticides in potable water supplies.

CAST has reported its position by stating that surface waters used for drinking by many livestock are normally higher in concentration of pesticides than most municipal supplies. Now that the chlorinated-hydrocarbon pesticides with long half-lives are being replaced with pesticides having shorter half-lives, the pesticide residues in waters consumed by livestock should have less effect, or at least no more effect, on livestock than previously. Although the possibility of toxicity of pesticides in livestock drinking water exists as a result of accidental or purposeful addition of large quantities of certain pesticides to small volumes of water, the fact is that no cases of toxicity of pesticides in the drinking water for livestock ingesting the water have been reported. Moreover, there is no evidence that pesticide residues in livestock products have had any unfavorable effect upon human beings. Hence, there is no evidence that pesticides in livestock drinking water present aproblem. Under these circumstances, a "no limit" tolerance would seem reasonable, with the levels of pesticide residues in water being controlled by the regulations governing the use of pesticides.

From an animal husbandry standpoint, it is sometimes easy to incriminate the water as a cause of poor performance and nonspecific disease conditions in livestock. However, an informed survey of veterinary diagnostic laboratory personnel in Iowa, Illinois, Indiana, Wisconsin, Missouri, Oklahoma, Kansas, Nebraska, and South Dakota failed to reveal any major animal health problems associated with water quality. All laboratories related case reports of individual, isolated circumstances of well and water contamination, but by and large, they thought water quality problems were minimal in their specific areas. This indicates that a large and varied number and kind of livestock and poultry are consuming many different kinds and qualities of water with generally very few adverse effects.

The interpretation of the significance of the specific laboratory data should be done carefully, taking into consideration other evidence presented in the particular case. Positive chemical findings are not always evidence of intoxication, and negative findings do not always indicate a lack of disease. It is imperative that attempts to evaluate water quality in the face of animal health problems include obtaining a thorough history, making astute observations, and asking intelligent questions. Properly prepared tissue specimens and other suspected material or water should be sent without delay to a qualified laboratory for examination. All information that can be obtained regarding the case should accompany the specimens to the laboratory. Cooperation and communication between the livestock producer, the veterinarian, and the laboratory can usually result in a rapid, proper diagnosis.

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