


FEEDLOT DESIGN AND CONSTRUCTION

5. Water quality

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Introduction

The water supply for feedlots can come from a number of sources with different water quality. Water sources include surface water (dams, rivers, creeks, channels), groundwater (bores, wells) or municipal supply.

In evaluating a feedlot water source, emphasis is generally placed on the chemical and physical characteristics of the water as they relate to cattle drinking water.

Cattle are sensitive to water taste and odour and may drink less if the water is unpalatable. Newly arrived cattle may be reluctant to drink water that has an unusual odour or taste, causing short-term stress. Contaminated water sources can affect the animal's water intake and animal performance or health.

Problems with water quality may have a chemical basis (e.g. pH or concentrations of certain elements) or may be due to physical causes (e.g. turbidity when the water is cloudy with suspended solids) or biological (algae). Some problems may be obvious while others may require more extensive analysis and treatment.

Water from some sources may be of an unsuitable quality for an intended use. Specific uses may need different quality e.g. good quality river water may be used successfully for irrigation but because of its sediment load, be unacceptable for cattle drinking water or boiler feedwater. Similarly, groundwater of excellent quality for cattle drinking water may be too corrosive for boiler feedwater use without appropriate treatment.

Design objectives

The design objectives for feedlot water quality are to provide levels that

- do not affect livestock water intake
- do not affect livestock health
- do not affect livestock performance
- do not affect the health of people
- minimise maintenance requirements on water supply and distribution infrastructure
- can be suited to other uses such as boiler water, vehicle and machinery washing.

Mandatory requirements

Compliance with

- Australian Animal Standards and Guidelines for Cattle (DAFF, 2013)
- National Guidelines for Beef Cattle Feedlots in Australia (MLA, 2012a) which states that a feedlot water supply is suitable for quality for stock use
- National Feedlot Accreditation Scheme (AUS-MEAT, 2013)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality – quality standards for beef cattle drinking (2000) (ANZECC and ARMCANZ 2000)
- relevant state and local authority codes and regulations as applicable to feedlot development in regards to water quality.

Technical requirements

Evaluation of water quality depends on its specific use within a feedlot. Information related to drinking water quality requirements for livestock, other intended uses at a feedlot and water sampling and testing guidelines are outlined in the following sections.

Assessing water quality

Water quality should be assessed before and sometimes during use.

Water quality assessment is generally based on

- physical/organoleptic properties (odour, taste, turbidity, temperature)
- physiochemical properties
- excess nutrients
- toxic substances
- microbiological agents

Physical/organoleptic properties (odour, taste, turbidity, temperature)

Physical properties include temperature and turbidity; organoleptic properties are those aspects experienced by the senses including odour, taste and colour.

Physiochemical properties

Physiochemical properties deal with the physical properties and the chemical composition, and include salinity, sodicity, hardness, pH, total dissolved solids and total dissolved oxygen.

Excess nutrients

The excess of certain nutrients in water supplies can adversely affect livestock health and potentially the environment. Nitrogen in the form of nitrate, and sulphate in the form of calcium, iron, sodium and magnesium salts, can affect the performance of cattle.

Toxic substances

Toxic substances can be defined as a broad group of chemicals capable of causing a health hazard to livestock and/or people working at the feedlot. These substances include

- heavy metals, including aluminium, arsenic, mercury, lead, copper, zinc and cadmium
- organophosphates found in pesticides, insecticides and herbicides
- hydrocarbons
- chemicals e.g. fluoride.

Microbiological agents

Bacteria, viruses, parasites and algae can be found in water sources. While most microorganisms are harmless some, such as blue-green algae, can affect livestock health and reduce performance. A contaminated water source can spread a pathogen (disease-causing agent) quickly throughout the feedlot; for example, leptospirosis can be spread through water supplies.

Water quality should be assessed by collection and analysis of water samples.

Fountains help aerate and cool artesian water and/or storage water during hot weather.

Drinking water can become extremely hot if steel or plastic water pipes are exposed to solar radiation.

Surface water sources can become stagnant during extended periods of dry weather, drought or low flow. Nutrient enrichment and higher water temperatures can generate algal blooms that may contain blue-green algae (cyanobacteria). Livestock have become sick or died from drinking water containing toxins (microcystins) released by blue-green algae.

Evaluating the content of water is relatively straightforward. The major difficulty is establishing levels at which animal health, welfare and productivity may be affected. Advice on site-specific water quality issues should be obtained from a suitably qualified and experienced nutritionist or veterinarian.

Cattle drinking water

Factors that may affect acceptability of drinking water for cattle include

Temperature

Cattle generally prefer water at or below body temperature, and avoid warmer water. They need cool drinking water to help maintain their body temperature during periods of hot weather.

At higher ambient temperatures, cattle drink more water in relation to dry matter consumption. Typically, the optimum temperature of drinking water with regard to performance of the cattle should be about 16–18°C. When the water temperature is above 25°C, water consumption rises more sharply due to the initiation of sweating and increased respiration; above 30°C, cattle tend to drink more often, at least every two hours.

If the drinking water temperature is above 25°C, such as in artesian water, it may need to be cooled. Strategies for cooling water and then maintaining the cool temperatures include evaporative cooling of ponds, buried pipelines, covers on water storages, and smaller capacity water troughs with high water turnover. In evaporative cooling ponds, the water supply could be drawn from the bottom of the pond where it is coolest.

Acidity or alkalinity

Total alkalinity in water is a combined measure of bicarbonates, carbonates, and hydroxide ions as these increase the pH of water. The total alkalinity of water is always less than its total dissolved solids (TDS) or salinity, since TDS and salinity include the sum of the concentrations of all substances dissolved in water, not just bicarbonates, carbonates, and hydroxide ions.

Alkalinity is expressed either as pH or as titratable alkalinity in the form of bicarbonates and carbonates. Alkalinity measures do provide information about the various salt types present in the water, but may be measured and expressed as a concentration of $CaCO_3$ mg/L.

Alkalinity alone seldom limits the use of water for livestock; however, the precise level of alkalinity that causes problems is not well defined. A concentration level less than 500 $CaCO_3$ mg/L indicates good quality water, 500–1,000 $CaCO_3$ mg/L poor quality water that cattle can still tolerate, but over 1,000 $CaCO_3$mg/L may cause physiological and digestive impediments in cattle. In order to offset the alkaline pH, acidic ions are required.

Water pH is a measure of concentration of hydrogen ions. A pH of 7 is neutral, a value less than 7 indicates acidity and a value above 7 indicates alkalinity (Figure 1). Drinking water with pH between 6 and 9 is assumed acceptable for cattle and has little influence on rumen pH. However, water sources with a pH below 6.0 or above 8.5 should be further evaluated where unexplained herd health or performance issues occur.

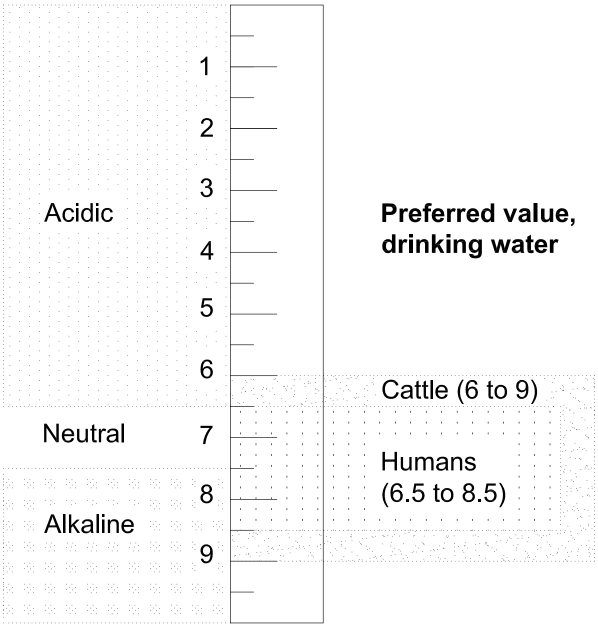

Figure 1. Guideline for pH value

Only pH and EC water quality parameters may normally be assessed in-situ. All other parameters must be tested at a NATA-accredited laboratory.

Total Dissolved Solids and Salinity

Salinity refers to the mass of dissolved salts in a solution and is typically determined indirectly by measuring total dissolved solids (TDS). These dissolved salts are often mainly sodium chloride but may include carbonates, nitrates, sulphates of calcium, magnesium and potassium. Generally, surface waters are lower in salts than underground water.

Dissolved salts in water are expressed in milligrams per litre (equivalent to parts per million – ppm) or in terms of the electrical conductivity of the water, measured in decisiemens per metre (dS/m) or microsiemens per centimetre (µS/cm).

1 dS/m = 1000 µS/cm = approx. 640 mg/L or 640 ppm.

Many factors influence the concentration of salts that cattle can tolerate in their drinking water. Cattle should be introduced to saline water gradually as they tend to become acclimatised to small changes in salinity but large increases can result in illness or even death.

Cattle can tolerate a TDS concentration up to 9,000 mg/L (13.6 dS /m) and for short periods, up to 10,000 mg/L (15.2 dS/m); levels above 10,000 ppm should never be used as water sources for beef cattle.

The ANZECC guidelines (ANZECC 2000) suggest that the desirable maximum TDS concentration for healthy growth of beef cattle is 4000 mg/L (6.25 dS/m), but it is generally recommended that the TDS concentration should not exceed 5,000 mg/L for cattle drinking watering purposes (see Table 1).

Table 1. TDS concentration for drinking water for livestock (mg/L)

Stock	Desirable maximum concentration for healthy growth	Maximum concentration at which good condition might be expected*	Maximum concentration that may be safe for limited periods*
Beef cattle	4,000	4,000–5,000	5,000–10,000
Horses	4,000	4,000–6,000	6,000–7,000

** The level depends on the type of feed.*
Adapted from Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000.

Cattle are less tolerant of saline water during hot or dry periods. In summer and during dry periods, evaporation increases the salinity of water in dams, troughs and rivers, so it is wise to check salinity if the water supply is naturally salty. Flushing troughs frequently should help to prevent salts from concentrating.

When formulating rations, the salt content of the water should be considered and the salt content of the ration may need to be reduced.

Hardness

Hardness, alkalinity and salinity are not the same. Hardness is the total concentration of calcium and magnesium in water, whereas salinity includes other dissolved solids. Hard water per se is not detrimental to livestock unless the water has a high level of salinity.

Water hardness is defined in terms of calcium carbonate ($CaCO_3$, also known as 'lime'). Hardness is a measure of the concentration of divalent metallic cations (++ charged) dissolved in water and is generally expressed as the sum of calcium and magnesium concentrations expressed as equivalents of calcium carbonate. Other divalent metallic cations such as iron and manganese can contribute to hardness, but concentrations are usually much lower than calcium and magnesium.

Total hardness consists of temporary or carbonate hardness and permanent or non-carbonate hardness; the former is removed by boiling, the latter is not. The removal of hardness is referred to as water softening.

Table 2. Calcium and magnesium concentrations and hardness

Description of water	Hardness expressed as $CaCO_3$ mg/L
Soft	0–50
Moderate	51–75
Moderately hard	75–150
Hard	150–300
Very hard	>300

Hard waters can cause problems in low-pressure and low-flow watering systems as accumulation of white mineral scale (insoluble calcium and magnesium carbonate deposits) can eventually restrict flow rates in pipelines. Water softeners are used to trap some of the calcium carbonate before it forms this white mineral scale.

Nutrients

(a) Nitrates

Water contamination with nitrates from manure, sewage or fertilisers becomes a serious concern when feed supplies contain high levels of nitrates.

Toxicity occurs when nitrates (NO_3) are converted to nitrites (NO_2) in the rumen of cattle. Nitrate poisoning is generally chronic and can result in reduced feed intake and in severe cases, death.

Nitrate-nitrogen levels in cattle drinking water of 10 mg/L (44 mg/L NO_3) or less are generally considered safe, levels between 10 and 100 mg/L are questionable, levels over 100 mg/L (443 mg/L NO_3) are generally considered unsafe (National Research Council, 1974).

The conversion is 1 gm/L NO_3–N = 45.43 4.43 mg/L NO_3

(b) Nitrites

Ingestion of nitrite leads to a more rapid onset of toxic effects than nitrate.

Confusion can arise concerning guideline values for nitrite (NO_2), because similar to nitrates, concentrations are sometimes reported on the basis of their respective nitrogen contents, that is, as nitrite–nitrogen (NO_2–N). The conversions are as follows:

$$1 \text{ mg/L } NO_2\text{–N} = 3.29 \text{ mg/L } NO_2$$

Water with a concentration of nitrite exceeding 30 mg/L (NO_2) (10 mg/L nitrite–N) may be hazardous to cattle health.

(c) Magnesium

Magnesium is an essential element for animal nutrition. Drinking water from natural sources usually contains magnesium but levels may vary greatly with location and often with season. Magnesium is present in feedstuffs in variable amounts, especially in forages.

There is no current ANZECC guideline for threshold magnesium concentrations in livestock drinking water.

(d) Fluoride

Fluoride occurs naturally in geological formations and concentrations vary depending on the location. Water from some bores has high fluoride concentrations and this can be rapidly increased by evaporation.

Fluorine is a cumulative toxin; thus animals that live longer (e.g. breeding cattle) are more likely to develop chronic fluorosis.

ANZECC guidelines (2000) state that fluoride concentrations greater than 2 mg/L in drinking water for livestock may be hazardous to animal health. If livestock feed contains fluoride, the trigger value should be reduced to 1.0 mg/L.

(d) Sulphates

Sulphate is present in most water sources and is commonly found in the form of calcium, iron, sodium, and magnesium salts, all of which act as laxatives. Elevated levels of these salts can make the water taste objectionable to cattle.

Reeds around water storages may adversely affect water quality.

Sulphates measured as SO_4 should ideally be present in concentrations of less than 500 mg/L. Sulphates present at concentrations of 500–1,000 mg/L indicate poor quality water that cattle may adjust to. Water intake starts to fall at sulphate concentrations of 1,000–2,000 mg/L and continues to drop as sulphate concentrations increase beyond these levels. Levels of sulphate greater than 2,000 mg/L may cause chronic or acute health problems (ANZECC, 2000).

Toxic compounds

Many metal elements are essential nutrients for cattle health but, in excess, may cause chronic or toxic effects. Water from certain sources may contain toxic levels of some metal elements.

The recommended ANZECC guidelines for metal concentrations below which there is a minimal risk of toxic effects are provided in Table 3.

Table 3. Recommended safe levels of heavy metals and metalloids in cattle drinking water (ANZECC 2000)

Metal or metalloid	Upper-limit guideline* (mg/L)
Aluminium	5
Arsenic	0.5
Beryllium	0.1
Boron	5
Cadmium	0.01
Chromium	1
Cobalt	1
Copper	1
Fluoride	2
Iron	not sufficiently toxic
Lead	0.1
Manganese	not sufficiently toxic
Mercury	0.002
Molybdenum	0.15
Nickel	1
Selenium	0.02
Uranium	0.2
Vanadium	0.1
Zinc	20

** Higher concentrations may be tolerated in some situations.*

Dirty drinking water can reduce animal performance.

Microbiological agents

A variety of microbial pathogens such as bacteria, viruses, protozoa and parasites can be transmitted to livestock from drinking water sources. The risk of contamination is greatest in surface waters that are directly accessible by livestock or that receive runoff or drainage from a manure source. Groundwater contamination by pathogens has generally been considered to be low.

A contaminated water source can spread a pathogen (disease-causing agent) quickly throughout the feedlot.

The pathogens of most concern include enteric bacteria such as *Escherichia coli*, *Salmonella* and to a lesser extent, *Campylobacter jejuni* and *Campylobacter coli, Yersinia enterocolitica* and *Yersinia pseudotuberculosis*. Other bacterial diseases known to affect livestock that may be transmitted through water supplies include *Leptospira* (leptospirosis), *Burkholderia pseudomallei* (melioidosis), *Pseudomonas*, and *Clostridium botulinum* (botulism), *Mycobacteria* (pulmonary disease) and *Cyanobacteria* (blue-green algal toxicosis) (ANZECC 2000).

Dirty water troughs can transmit some cattle diseases.

Coliforms

Because pathogens are not easily detected in water, their presence is inferred by using indicator organisms such as *Escherichia coli* measured in colony-forming units (CFU) per mL.

Since *E. coli* bacteria occur from direct contamination by livestock or human waste, their occurrence is much more serious than total coliform bacterial contamination. *E. coli* bacteria can be found frequently in water troughs due to direct contact with cattle; troughs should be cleaned frequently.

ANZECC guidelines recommend less than 100 thermotolerant (faecal) coliforms/100 mL (median value) for livestock drinking water (ANZECC 2000).

Algal growth in stagnant water. Some types of algae (e.g. blue-green algae) produce mycotoxins which are toxic to livestock.

Cyanobacteria (Blue-green algae)

Algae can grow in surface water supplies and water troughs that are not regularly cleaned. Algal blooms may contain a type of photosynthetic bacteria called cyanobacteria (blue-green algae) which produce a microcystin that can be toxic to livestock. If sufficient quantities of the toxin are consumed, paralysis and respiratory failure occurs rapidly. Dead animals are usually found close to the suspect water source.

Waters contaminated with microcystins will have a mouldy, musty or septic tank odour. Although odour is not a test that is typically conducted, waters with these contaminants will also have high TDS, nitrogen, and phosphorus concentrations.

ANZECC guidelines state an increased risk to livestock health is likely when cell counts of Microcystis exceed 11,500 cells/mL and/or concentrations of microcystins exceed 2.3 µg/L expressed as microcystin-LR toxicity equivalents (ANZECC 2000).

Cattle drinking from trough with algal growth.

All algal blooms should be treated as possibly toxic. Removing animals from affected areas and withdrawing the water source until the algae are identified and the level of toxin determined is the only sure method of preventing poisoning. Care should be taken to limit the growth of algae in water for livestock consumption.

Water troughs should be cleaned on a regular basis to prevent algae buildup. Covers or chlorination can prevent algal blooms in temporary water storages.

Boiler feedwater quality

A steam boiler plant must operate safely with maximum combustion and efficient heat transfer, and this is profoundly affected by the quality of the water used to produce the steam in the boiler.

Boilers need to operate under the following criteria

- Freedom from scale – hard water will cause scaling of the heat transfer surfaces and make frequent cleaning of the boiler necessary.
- Freedom from corrosion and chemical attack – water containing dissolved gases, particularly oxygen, will corrode the boiler surfaces, piping and other equipment.

If the impurities in the boiler feedwater are not dealt with properly, they will be carried over into the steam system and cause problems such as

- contamination of the surfaces of control valves and heat transfer surfaces
- restriction of steam trap orifices.

Water treatment for boiler feedwater

Typically on steam boilers, feedwater is treated before the boiler. External water treatment processes (Table 4) can be listed as

- reverse osmosis
- lime, lime/soda softening
- ion exchange.

The suitable water treatment process will depend on the quality of raw water.

Three types of impurities (suspended solids, dissolved solids and dissolved gasses) exist in all supplies and can cause a wide range of problems in boilers. Generally, groundwater contains more dissolved solids and less suspended solids and dissolved gases whereas surface water contains more suspended solids and dissolved gases and less dissolved solids.

Table 4. Common treatment processes

Issue	Suspended solids	Dissolved solids	Dissolved gases
Treatment options	Filtration	Ion exchange softening	De-aeration
	Clarification	De-mineralisation	De-gasification
		Reverse osmosis	De-alkalisation

The optimum pre-treatment scheme for each plant must take the entire system into account. Feedlots should consult boiler engineers for professional advice on the correct water treatment system required for the boiler to be used.

Table 5, Table 6, Table 7 and Table 8 provide water quality guidelines for high-pressure boilers from different organisations – Tables 5 and 6 from American Society of Mechanical Engineers (ASME 2013), Tables 7 and 8 from American Boiler Manufacturers Association (ABMA 2005).

Table 5. Recommended feedwater quality guidelines for water tube boilers (ASME 2013)

Boiler feedwater						
Drum pressure psi	Dissolved O_2 ppm	Iron ppm	Copper ppm	Total hardness ($CaCO_3$) ppm	pH @ 25°C	Oily matter ppm
0–300	7000	0.100	0.050	0.300	8.3–10.0	1
301–450	7000	0.050	0.025	0.300	8.3–10.0	1
451–600	7000	0.030	0.020	0.200	8.3–10.0	0.5
601–750	7000	0.025	0.020	0.200	8.3–10.0	0.5
751–900	7000	0.020	0.015	0.100	8.3–10.0	0.5
901–1000	–	0.020	0.015	0.050	8.3–10.0	0.2
1001– 1500	–	0.010	0.010	0.00	8.8–9.6	0.2
1501–2000	–	0.010	0.010	0.00	8.8–9.6	0.2

Table 6. Recommended feedwater quality guidelines for water tube boilers (ASME 2013)

Boiler feedwater			
Drum pressure psi	Silica (SiO_2) ppm	Total Alkalinity ($CaCO_3$) ppm	Specific Conductance (micro-ohms/cm) (unneutralised)
0–300	150	700	7000
301–450	90	600	6000
451–600	40	500	5000
601–750	30	400	4000
751–900	20	300	3000
901–1000	8	200	2000
1001– 1500	2	0	150
1501–2000	1	0	100

Table 7. Recommended feedwater quality guidelines for water tube boilers (ABMA 2005)

Drum pressure psi	Total dissolved solids (TDS) ppm	Total alkalinity (CaCO3) ppm	Total Suspended Solids ppm
50–300	3500	700	15
301–450	3000	600	10
451–600	2500	500	8
601–750	1000	200	3
751–900	750	150	2
901–1000	625	125	1

Table 8. Maximum allowable impurities in boiler water quality from ABMA (2006)

Boiler feedwater				
Sodium sulphite (Na_2SO_3) ppm	Sodium chloride (NaCl) ppm	Sodium phosphate (Na_3PO_4) ppm	Sodium sulphate (Na_2SO_4) ppm	Silica oxide (SiO_2) ppm
1.0	10.0	25.0	25.0	0.20

Further reading

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