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WATER QUALITY IN AGRICULTURE: **Risks and risk mitigation**

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Chapter 7

Livestock and water quality

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Global population growth has provoked an increase in global water demand across all sectors, and the livestock sector is no exception. Agriculture accounts for approximately 70 percent of available freshwater supply of which global livestock production represents about 30 percent. This proportion includes rain and irrigation water used for the production of feed and withdrawals for livestock husbandry (Mekonnen & Hoekstra, 2012), with a large proportion allocated to beef production. The relationship between water quality and livestock is double-edged: livestock require quality water, but the waste they produce can deteriorate water quality.

Nitrogen (N) is one of the key parameters for livestock drinking water quality, however livestock is also responsible for major nitrogen releases into nature. One-third of human-induced reactive nitrogen losses can be traced to livestock systems. Most nitrogen is emitted in two forms: Nitrate (NO_3^-, 45 percent), which degrades water quality in freshwater and coastal systems, and ammonia (NH_3, 41 percent), which contributes to air pollution and causes eutrophication and acidification (Mueller & Lassaletta, 2020). N emissions are also precursor to the formation of fine particles which enter the respiratory tract affecting public health (Cohen *et al.*, 2017).

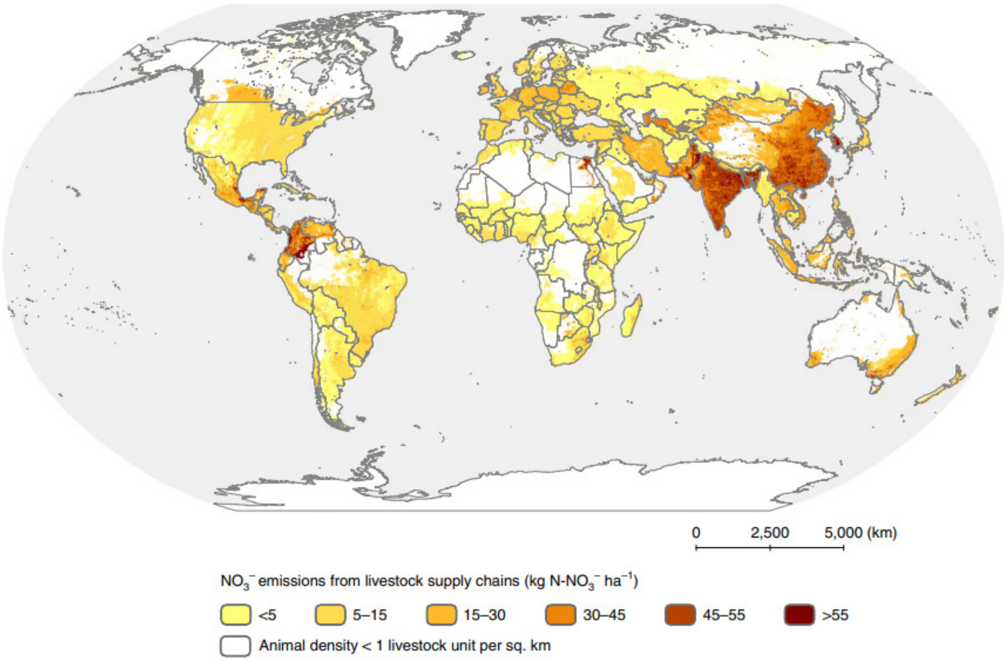
Figures 7.1 and 7.2 show the global distribution of nitrogen emissions from livestock supply chains taking into consideration the diversity of livestock species, systems, production intensity, and the origins and management of different animal feed (Uwizeye *et al.*, 2020).

The Livestock Environmental Assessment and Performance Partnership (FAO LEAP), a multi-stakeholder initiative designed to build consensus on how to assess the environmental impacts of livestock systems, has developed several FAO guidance documents that consider, among others, the water footprint of livestock based on the life cycle assessment methodology and data collection in accordance with ISO 14046:2014[1]. The water footprint of large ruminants consists primarily (often by over 90 percent) of the water needed for (irrigated) feed production, in addition to the direct water footprint associated with drinking water and the consumption of service water (Chapagain & Hoekstra, 2003). The guidelines suggest discussion of the impact of livestock supply chains on water consumption and water quality in defined system boundaries (FAO, 2015).

While livestock water use is associated with livestock watering, feedlots, dairy operations, servicing (including farm and slaughterhouse cleaning), and other on-farm needs, this chapter focuses (i) on the water needs and quality that impact animal health and production, and (ii) the possible burden of livestock waste on water resources.

[1] ISO 14046:2014 specifies principles, requirements and guidelines related to water footprint assessment of products, processes and organizations based on life cycle assessment (LCA).

Figure 7.1. Global distribution of nitrate (NO_3) emissions from livestock supply chains



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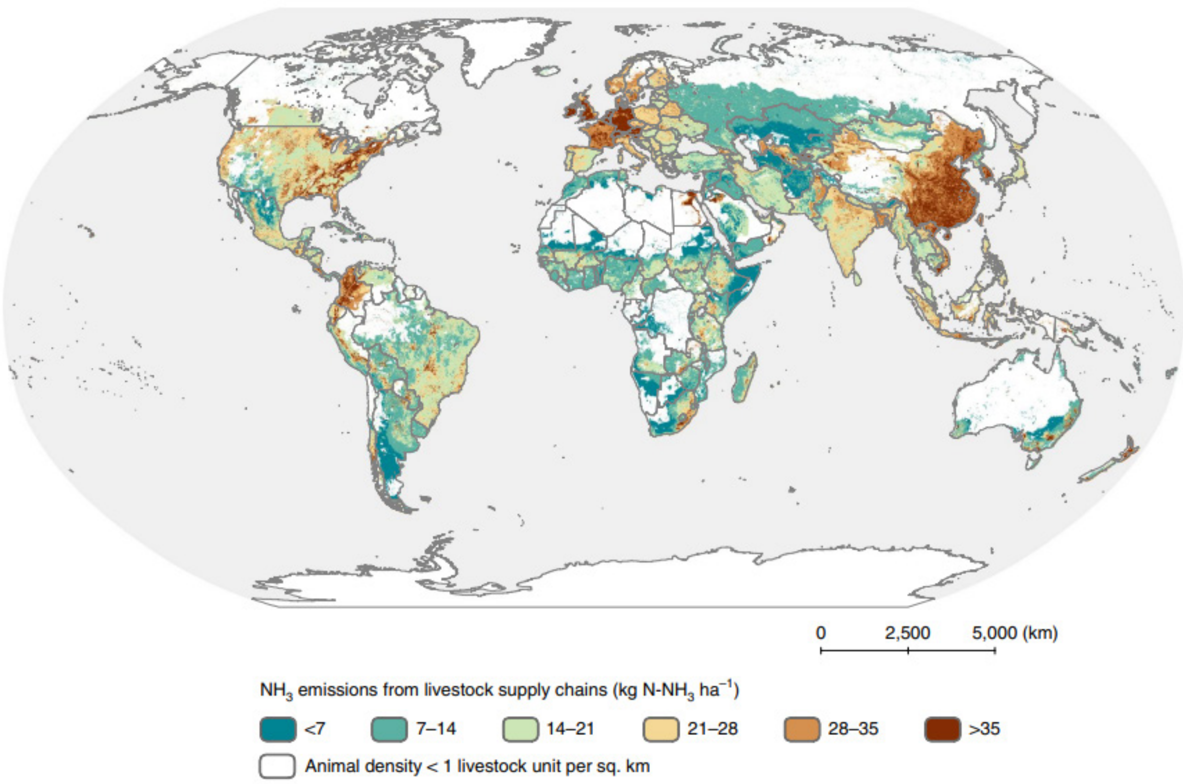
Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Figure 7.2. Global distribution of ammonia (NH_3) emissions from livestock supply chains



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7.1. Water quality specifications for selected parameters potentially affecting livestock health

The water requirements of livestock depend on physiological and environmental conditions. Consumption may vary greatly depending on the species, size and age of the animal, the physical state, the level of activity, food intake, the quality and temperature of water, and the environmental temperature. Because water plays a critical role in animal health, it is essential to provide clean and sufficient water for livestock.

The vast majority of actual water required by animals is obtained as drinking water, followed by the water content of the feed. It is estimated that livestock bodies contain between 60 percent and 70 percent water, which is necessary for maintaining body fluids and proper ion balance; as well as functions such as digestion, absorption and metabolizing nutrients; the elimination of waste material and excess heat from the body; the provision of a fluid environment for foetuses; and transporting nutrients to and from body tissues. Several parameters should be considered when assessing water quality for livestock. These are:

- sensory (organoleptic) attributes such as odour and taste;
- physiochemical properties (pH, salts/total dissolved solids, hardness);
- chemical composition
    - toxic compounds (heavy metals, pesticides, herbicides, etc.);
    - excess minerals or compounds such as nitrates;
    - biological contaminants (bacteria, algae, etc.);
    - spills of petroleum, etc.

Water quality monitoring and evaluation is an ongoing process that requires regular access to a laboratory. The adverse effects of water on animal health and production depend on the location and might be related to high concentrations of minerals (e.g. nitrates and nitrites, sulfate salts, Mg), high levels of pathogenic bacteria causing infections, heavy growth of blue-green algae, and water contamination with chemical substances associated with agriculture and industrial activity such as pesticides and herbicides. Some of the thresholds for water quality parameters are presented below.

7.1.1. Salinity-related toxicity

Excessively saline water may cause salt poisoning in livestock or stop animals from drinking, leading to a loss of production. Tolerance levels of salts[2][3][4] are commonly measured in terms of total dissolved solids (TDS), which have been assessed for a number of livestock/animal species (Table 7.1).

[2] https://www.agric.wa.gov.au/livestock-biosecurity/water-quality-livestock?page=0%2C0#smartpaging_toc_p0_s5_h2
[3] https://www.msdvetmanual.com/toxicology/salt-toxicosis/salt-toxicosis-in-animals
[4] https://extension.missouri.edu/eq381#mineralized

Table 7.1. Approximate tolerances of livestock to dissolved salts (salinity) in drinking water (TDS in mg/L)

Livestock	A: No adverse effects on animals expected (mg/L)	B: Animals may initially exhibit reluctance to drink or there may be some scouring, but stock should adapt without loss of production (mg/L)	C: Loss of production and decline in animal condition and health would be expected. Livestock may tolerate these levels for short periods if introduced gradually (mg/L)
Beef cattle (mature, on dry pasture)	0–4 000	4 000–5 000	5 000–10 000
Beef cattle (feedlots)	0–4 000		>4 000b
Dairy cattle (mature, dry)	0–2 400	2 400–4 000	4 000–7 000
Dairy cattle (milking)			3 500
Sheep (mature, on dry pasture)	0–4 000	4 000–10 000	10 000–13 000a
Sheep (mature, dry, feedlots)	0–4 000		>7 000b
Sheep (mature, dry confinement feeding)	0–4 000		>7 000c
Sheep (weaners, lactating and pregnant on pasture)	0–4 000		6 600
Sheep (lambs, intensive feeding)	0–4 000		>4 000b
Horses	0–4 000	4 000–6 000	6 000–7 000
Poultry	0–2 000	2 000–3 000	3 000–4 000
Pigs	0–4 000	4 000–6 000	6 000–8 000

[a] Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production.

[b] Intensive feeding for growth.

[c] Confinement feeding for maintenance.

Source: DPIRD https://www.agric.wa.gov.au/livestock-biosecurity/water-quality-livestock

Salinity caused by the presence of salts is strongly correlated with electrical conductivity (EC) of the water. It is therefore more common and practical to measure conductivity rather than TDS, and subsequently convert the EC value to TDS[5]. The EC units used are milliSiemens per metre (mS/m). Table 7.2 summarizes the guidance values of EC thresholds applicable to livestock.

[5] See www.agric.wa.gov.au/livestock-biosecurity/water-quality-livestock.

Table 7.2. Electrical conductivity specifications for livestock and poultry.

Water salinity (EC) (dS/m)	Rating	Remarks
<1.5	Excellent	Usable for all classes of livestock and poultry.
1.5–5.0	Very satisfactory	Usable for all classes of livestock and poultry. May cause temporary diarrhoea in livestock not accustomed to such water; watery droppings in poultry.
5.0–8.0	Satisfactory for livestock	May cause temporary diarrhoea or be refused at first by animals not accustomed to such water.
	Unfit for poultry	Often causes watery faeces, increased mortality and decreased growth, especially in turkeys.
8.0–11.0	Limited use for livestock	Usable with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid use for pregnant or lactating animals.
	Unfit for poultry	Not acceptable for poultry.
11.0 – 16.0	Very Limited Use	Unfit for poultry and probably unfit for swine. Considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species. In general, use should be avoided, although older ruminants, horses, poultry and swine may subsist on waters such as these under certain conditions.
>16.0	Not Recommended	Risks with such highly saline water are so great that it cannot be recommended for use under any conditions.

Source: Ayers, R.S. & Westcot, D.W. 1994. Water quality for agriculture. FAO Irrigation and Drainage Paper 29, Rev. 1. Rome

Among salinity-causing salts, those containing sulphate can be particularly relevant for livestock, especially in location where the hot climate evaporates surface waters, increasing salt concentrations. Table 7.3 gives related guidelines (German, Thiex & Wright, 2008) in this regard. In general, the maximum concentration of sulphate (SO_4) in drinking water for livestock, which is often set as 1 000 mg/l, depends significantly on the additional sulphate intake through feed (i.e. the dietary sources). Water consumption by cattle begins to decrease at sulphate (SO_4) levels of 2 500 to 3 000 mg/L, which will lead eventually to dehydration and death[6].

[6] https://waterquality.montana.edu/well-ed/interpreting_results/fs_livestock_suitability.html and https://agriculture.canada.ca/en/agriculture-and-environment/agriculture-and-water/livestock-watering/water-quality-impacts-livestock

Table 7.3. A guide to the use of water containing sulfates for livestock and poultry

Sulfate (SO_4) mg/L or ppm	Comments
Less than 250 (poultry)	Recommendations for poultry are variable. The more conservative guidelines indicate that sulfate content above 50 mg/L may affect performance if magnesium and chloride levels are high. Higher sulfate levels have a laxative effect.
Less than 1500 (livestock)	For livestock, no harmful effects- except some temporary, mild diarrhea near upper limit, and animals may discriminate against the water due to taste at the upper limit. The calculations of total sulfur intake is recommended when using sulfur-containing feeds (e.g., molasses, distiller's grains, corn gluten feed).
1500-2500	For livestock, no harmful effects- except some temporary diarrhea. In cattle this water may contribute significantly to the total dietary sulfur intake. May cause a reduction in copper availability in ruminants. Calculating total sulfur intake is recommended.
2500-3500	Poor water for poultry, especially turkeys. Very laxative, causing diarrhea in livestock that usually disappears after few weeks. Sporadic cases of sulfur- associated polioncephalomalacia (PEM) are possible. May cause substantial reduction in copper availability in ruminants. The calculation of total sulfur intake is recommended.
3500-4500	Very laxative. Unacceptable for poultry. Not recommended for use for pregnant or lactating ruminants or horses, or for ruminants fed in confinement. Sporadic cases of sulfur-associated polioncephalomalacia (PEM) are likely. May cause substantial reduction in copper availability in ruminants. The calculation of total sulfur intake is recommended.
Over 4500	Not recommended for use under any conditions. The calculation of total sulfur intake is highly recommended. Increased risk of mortality and morbidity.

Source: German, D., Thiex, N. & Wright, C. 2008. Interpretation of water analysis for livestock suitability. Brookings, SD, South Dakota State University, South Dakota counties, and U.S. Department of Agriculture

Sulphate containing salts are often sodium ($Na_2SO_{4)}$ or magnesium ($MgSO_4$) based. In general, sodium concentrations under 1 000 mg/l should be protective for livestock, unless sulphate levels are also high (Table 7.4). Sodium values above 5 000 mg/l can cause serious effects and death. Short-term exposure should not exceed 4 000 (MSU, 2021).

Table 7.4. A guide to the use of water containing sodium for livestock and poultry

Sodium (Na) mg/L or ppm	Comments
Less than 50 (poultry)	Sodium levels pose little risk to poultry.
50 – 1000 (poultry)	Recommendations are extremely variable and sodium itself poses little risk; however, water with sodium over 50 mg/L (ppm) may affect the performance of poultry if the sulfate or chloride is high. Sodium levels greater than 50 mg/L are detrimental to broiler performance if the sulfate level is also 50 mg/L or higher and the chloride level is 14 mg/L or higher. Excessive sodium has a diuretic effect for poultry.
Less than 800 (livestock)	By itself, sodium poses little risk to livestock, but its association with sulfate is a concern. Water with over 800 mg sodium /L can cause diarrhea and a drop in milk production in dairy cows. High levels of sodium, a major component of salt, may necessitate adjustments to rations. Care should be taken when removing or reducing salt from swine and diary rations to ensure a chlorine deficiency does not result. Salt may be reduced in swine diets if the sodium in the water exceeds 400 mg/L.

Source: German, D., Thiex, N. & Wright, C. 2008. Interpretation of water analysis for livestock suitability. Brookings, SD, South Dakota State University, South Dakota counties, and U.S. Department of Agriculture

Magnesium-based salts in cattle trigger a stronger sulfate response than sodium-based salts for which many animals have developed a recognized appetite (Grout *et al.*, 2006). Table 7.5 shows the related drinking water guidelines for magnesium.

Table 7.5. Specifications for magnesium in drinking water for livestock

Livestock	Magnesium (mg/l)
Horses	250
Beef cattle	400
Cows (lactating)	250
Adult sheep on dry feed	500
Ewes with lambs	250

Source: Ayers, R.S. & Westcot, D.W. 1994. Water quality for agriculture. FAO Irrigation and Drainage Paper 29, Rev. 1. Rome

7.1.2. Trace elements

Trace elements can be important for livestock growth, but become a problem if they exceed certain thresholds. In particular, metals in drinking water can lead to toxic outcomes in animals. Some metals are geogenic in origin (i.e. inherited with location), while others are introduced due to anthropogenic activities. As trace metals can accumulate slowly, monitoring should therefore be performed periodically. Table 7.6 gives the upper limits for selected contaminants.

Table 7.6. Specifications for limit values for trace metals in drinking water for livestock

Constituent (symbol)	Upper limit (mg/l)
Aluminium (Al)	5
Arsenic (As)	0.2
Beryllium (Be)[1]	0.1
Boron (B)	5
Cadmium (Cd)	0.05
Chromium (Cr)	1
Cobalt (Co)	1
Copper (Cu)	0.5
Fluoride (F)	2
Iron (Fe)	No reported toxicity
Lead (Pb)[2]	0.05-0.1
Manganese (Mn)[3]	0.05
Mercury (Hg)	0.01
Nitrate + Nitrite (NO_3-N + NO_2-N)	100[4]
Nitrite (NO_2-N)	10
Selenium (Se)	0.05-0.1
Vanadium (V)	0.1
Zinc (Zn)	24

[1] Insufficient data for livestock. The value for marine aquatic life is used here.
[2] Lead is accumulative and problems may begin at a threshold value of 0.05 mg/l.
[3] Insufficient data for livestock. The value for human drinking water is used here.
[4] These levels are rarely seen in surface water except in extremely contaminated water bodies, but can be found in groundwater.

Source: Ayers, R.S. & Westcot, D.W. 1994. Water quality for agriculture. FAO Irrigation and Drainage Paper 29, Rev. 1. Rome

Nitrate is a particular common contaminant strongly influenced by human activities. Nitrate intake occurs mainly through feed and drinking water. Elevated levels may be found in forage due to heavy use of nitrogen fertilizer in fields or other types of water pollution. While acute nitrate poisoning is rare, elevated levels of nitrates in water for livestock or poultry may result in possible effects, which are presented in Table 7.7.

Table 7.7. Possible effects of nitrates in water for livestock or poultry (in mg/L or ppm)

Nitrate level as NO_3 [a]	Nitrate level as NO_3-N [a]	Possible effects [b]
0 to 100	0 to 23	Unlikely for livestock or poultry
101 to 500	23 to 114	Possibility of reduced gains, increased infertility
501 to 1 000	115 to 227	The water should not harm livestock or poultry by itself, but in combination with normal nitrate intake through feed can result in distress symptoms (shortness of breath, rapid breathing)
over 1 000	over 227	Suffocation signs, lack of coordination or staggering, ultimately death of cattle, sheep or horses

[a] When a laboratory reports the concentration of nitrate, it might refer to the nitrate ion (NO_3-) or to the nitrogen within the nitrate ion (NO_3-N).
[b] Assumes normal or close to average nitrate levels in forage and feed.

Sources: Adams, R.S., McCarty, T.R. & Hutchinson, L.J. 2021. Prevention and control of nitrate toxicity in cattle. University Park, PN, Pennsylvania State University; German, D., Thiex, N. & Wright, C. 2008. Interpretation of water analysis for livestock suitability. Brookings, SD, South Dakota State University, South Dakota counties, and U.S. Department of Agriculture

7.1.3. Pesticides, herbicides and pharmaceutics

The Canadian Environmental Quality Guidelines online database contains a large range of pesticides, herbicides, other organic contaminants and heavy metals that may be found in livestock drinking water (CCME, 2021). A comparison of the different regulations governing these substances is found in Valente-Campos *et al.* (2014). Although drinking water can contain pharmaceutical residues, related guidelines for livestock have emerged only slowly as concentrations remained very low for many years compared, for example, with those of purposely administered antibiotics (e.g. through feed or water). The use of antibiotics for growth promotion purposes was banned in the European Union in 2006, and the use of sub-therapeutic doses of medically important antibiotics in animal feed and water became illegal in the United States on 1 January 2017. More bans are expected as awareness increases of the risk of transmitting drug-resistant bacteria to humans, accompanied by calls for standards for total livestock and poultry intake (including via water).

7.1.4. Water-borne microbial infections

Several microbes, some of them zoonotic in nature, have been associated with water transmission and disease outbreaks. The risk of contamination is greatest in surface waters (dams, lakes, dugouts, etc.) that are directly accessible by stock, or that receive runoff or drainage from intensive livestock operations or human waste. In comparison, groundwater is considered a low-risk source (Olkowski, 2009).

Bacterial pathogens: The pathogens of greatest concern in water supplies for farm animals include enteric bacteria such as *E. coli*, *Salmonella*, *Clostridium botulinum* and *Campylobacter jejuni*. The presence and survival of bacteria in natural aquatic ecosystems depends upon a number of factors, including nutrient content, exposure to direct sunlight and temperature, and competition with other microorganisms. Strict tolerance values for livestock have not been established. It is however often recommended that drinking water for livestock should contain less than 100 coliforms/100 ml.

Botulism and salmonellosis are two bacterial livestock diseases that may result from contamination of water with organic matter:

- Botulism is a rapid-onset, usually fatal disease caused by the botulinum toxin produced by the bacterium *Clostridium botulinum*. Typical signs include hindlimb weakness progressing to paralysis, collapse and death. Common sources of the toxin include animal carcasses, rotting organic material and poorly prepared silage. Treatment is rarely attempted but vaccines are available for disease prevention in cattle. For more information see www.agric.wa.gov.au/livestock-biosecurity/botulism-cattle.
- Salmonellosis of sheep is an infectious bacterial disease causing illness and death. It results from proliferation of salmonella bacteria in the gastrointestinal tract and other organs. A possible source can be faecal contamination of feed or water. Profuse diarrhoea is commonly present and pregnant ewes may abort. For more information see www.agric.wa.gov.au/livestock-biosecurity/salmonellosis-sheep.

Of particular importance are water sources such as reservoirs used by cattle and humans. Cattle are considered a primary source of *E. coli* O157, which is one of the Shiga toxin-producing *E. coli* (STEC) strains. These toxins usually do not cause disease in animals but may cause watery diarrhoea. Water contaminated with cattle faeces, as well as direct or indirect contact with live cattle, are considered major routes of human infection. Cattle that carry *E. coli* O157 can thus be asymptomatic, but in humans this pathogen creates severe zoonotic infections, and in many cases is the cause of death (Olkowski, 2009).

Protozoan: *Cryptosporidium spp*. are protozoan parasites that affect livestock, some of which are of public health importance due to their ability to cross over to humans. Transmission occurs via water, therefore, water sources in production systems should be monitored carefully. Among the many species which can infect human, cattle, small ruminants and poultry, *C. parvum* and e.g. *C. andersoni* are some of the most prevalent, affecting young livestock, especially pre-weaned ruminants (Fayer, 2004).

Algae: Livestock can be poisoned by drinking water contaminated with blue-green algae (*Cyanobacteira*) and associated natural toxins such as acute hepatotoxins, cytotoxins, neurotoxins and toxins causing gastrointestinal disturbance. Blue-green algae are a group of bacteria that include *Nodularia spumigena*, *Microcystis aeruginosa* and *Anabaena circinalis*. They can produce spectacular blooms which resemble iridescent green paint or curdled greenish milk on water surfaces. Algae multiply rapidly ("bloom") in shallow, stagnant and warm water when the water is contaminated by plant nutrients, including organic and faecal matter and phosphorus. Identification of cyanobacteria and especially the *Microcystis* species (Table 7.8) is difficult. The various species can be identified by experts with a microscope, but in the field such determination is limited to whether the bloom is filamentous (stringy) or planktonic. Filamentous algae are easily removed from water by hand, whereas planktonic algae/cyanobacteria are single celled and will slip through fingers. No toxin-producing cyanobacteria is of the filamentous type.

Table 7.8. Guideline for calculated tolerance levels (No Observed Effect Level) of microcystin LR toxicity equivalents and number of cells of Microcystis aeruginosa.

Livestock category	Body weight (kg)	Peak water intake (L/day)	Calculated total toxin level (µg/L)	Equivalent cell number (cells/mL)
Cattle	800	85	4.2	21 000
Sheep	100	11.5	3.9	19 500
Pigs	110	15	16.3	81 500
Chicken	2.8	0.4	3.1	15 500
Horse	600	70	2.3	11 500

Source: Olkowski. 2009. Livestock water quality: a field guide for cattle, horses, poultry, and swine. Ottawa, Agriculture and Agri-Food Canada

7.1.5 Good management practices for water quality to keep livestock healthy

The following recommendations should be considered as part of good practices for farm management:

- Assess water quality and quantity for effective production planning. If water quality is poor, livestock may drink less than they need or may stop drinking altogether. When animals drink less, they will eat less resulting in deterioration of their physiological condition. If they are lactating, milk production will reduce or cease.
- Learn from colleagues, veterinarians and water experts about water contaminants that are likely to negatively affect animal health in your area. Seek laboratory support to identify the key parameters of principal water sources (e.g. algae, salinity, pathogens, trace metals, chemicals organic materials, etc.) to determine which ones are likely to play a critical role. This assessment may have to be performed in both the rainy and dry seasons. In the rainy season, more pollutants will be washed into water bodies; in the dry season, salt concentration will increase due to evaporation and less dilution. Where water is scarce and expensive, storage pond cover sheets could be help reduce costs (Martínez Alvarez *et al.*, 2009).
- Develop a Risk Mitigation Plan to monitor critical water parameters on a regular basis and identify changes in water quality before they have an impact on animals. Monitoring livestock health is a particularly important component of risk mitigation due to potential difficulties in analysing possible contaminants. Establishing a working relationship with a veterinarian is essential to ensure that animal health and welfare and disease notification issues are addressed.
- Seek veterinary assistance to immediately investigate any signs of serious disease. The presence of water contaminants in livestock should be identified as early as possible, before the manifestation of adverse health effects in animals. Both producers and water specialists should be trained to recognize subtle adverse effects on growth rate, feed conversion ratio, reproductive success, milk yield and product quality.

Preventive hygiene measures and good management are currently the most important tools to control cryptosporidiosis as chemical disinfectants have shown mixed success. Ensure that animal manure does not enter the drinking water sources of livestock or of farmers downstream. Where drinking water is polluted consider treatment. Several methods and technologies are available to reduce and even eliminate the amount of different contaminates in water. In selecting a method, consider the cost effectiveness of the identified risk factors. Possible options include the following methods:

- *Activated carbon filters:* This method is based on passing water through a filter containing activated carbon granules. The contaminants attach to the granules and are removed. This method is able to remove mercury, some pesticides and volatile organic compounds, among others. Poor filter maintenance will decrease effectiveness, however, and may result in bacterial growth on the filters, potentially contaminating the water with pathogens. It is therefore important to replace the filters often, which increases operational costs.
- *Chlorination:* This is one of the most common methods applied in water treatment to reduce pathogens in drinking water for livestock as well as humans. The chlorination process is very effective when used in conjunction with a filtration system to remove large particles that can house bacteria. However, the chlorine content of the treated water should be closely monitored to avoid possible harm to animals (Olkowski, 2009).
- *Coagulation:* This method is used in livestock operations to remove fine particles, iron, arsenic, manganese and organics. The removal of particles prior to chlorination makes disinfection much more effective. Coagulation is a standard treatment for surface water prior to chlorination. The chemicals used in the process, such as aluminium sulphate (alum), neutralize the charge on the particles and cause them to coalesce into floc that can be removed by filtration or settling (Olkowski, 2009).
- *Sulfate reduction:* Present treatment technologies to reduce sulfates are costly. They include ion exchange and membranes, such as nanofiltration. Due to the high cost, the best option is usually to find another water source with a lower concentration of sulfates.

Avoid water sources that show elevated levels of cyanobacteria (blue algae). The prevention of cyanobacterial blooms is a more cost effective means of reducing the risk of toxicity than the typical water treatment process. Reducing the growth potential of cyanobacteria by lowering nutrient availability, for example, should be the primary goal when seeking to reduce the risks associated with cyanobacterial blooms (Downing, Watson & McCauley, 2001). Other options for eliminating blooms include the use of storage tank covering sheets for light shading (Craig *et al.*, 2005), or the application of chemical algaecides. There is evidence that copper sulfate added to pond water up to a concentration of 1 ppm (1 mg/l) will successfully kill algae blooms, but will also likely harm other types of aquatic life. The Canadian AAFC-PFRA recommends a lower dosage between 0.06 mg/l and 0.25 mg/l based on the surface area of the water body. Treatment at the beginning of the bloom at a low dosage is more effective than later treatment, as it allows the zooplankton to populate and assist in the control of algae and cyanobacteria. It is important to remember that a sudden release of toxins can occur when cyanobacterial blooms die. Hence, the use of chemical algaecides may not eliminate the risk of toxicity; in fact, the risk of toxin exposure may increase if the algaecide is introduced at the wrong time[7].

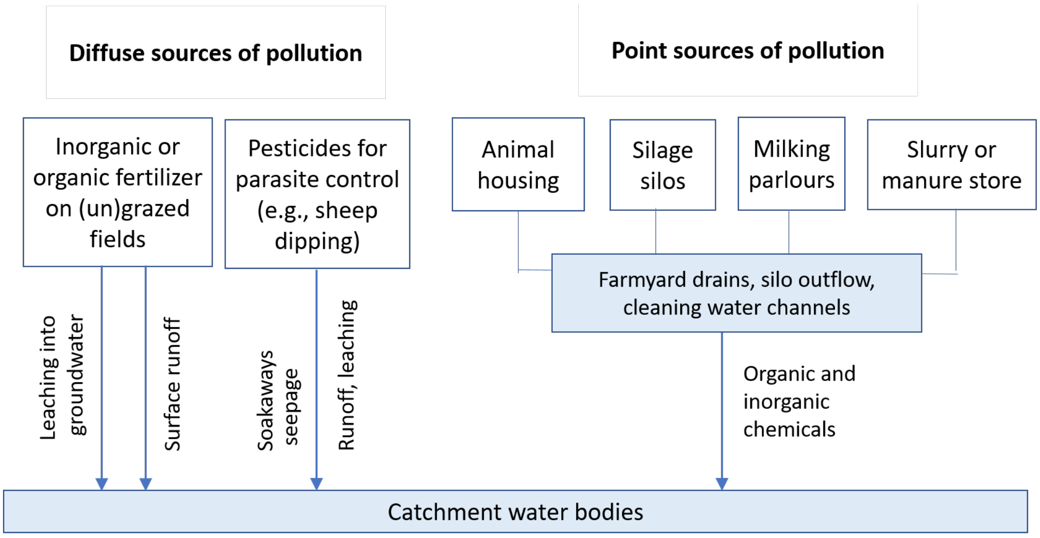
7.2. Livestock impact on water quality

The livestock sector is growing and intensifying faster than crop production in almost all countries, and the associated waste, including manure, has serious implications for water quality. Where livestock is concentrated, the associated production of wastes can surpass the buffering capacity of surrounding ecosystems, thereby polluting surface waters and groundwater (Mateo-Sagasta, Marjani Zadeh & Turral, 2017). Increased loss of nutrients in agricultural runoff has potentially

[7] www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf

serious ecological and public health implications. Nitrogen and phosphorus are of particular significance in this regard, as both can lead to aquatic eutrophication if stemming from diffuse pollution from pasture-based cattle and sheep systems, or point pollution from indoor systems, as it is common for pigs and poultry (Figure 7.3). Finally, feedlots are often located on the banks of watercourses where (nutrient-rich) animal waste (e.g. urine) is released directly into the water.

Figure 7.3. Pathways of diffuse and point sources of nutrients and farm effluent inputs to catchment waters in livestock farming areas



Source: Modified after Hooda, P.S., Edwards, A.C., Anderson, H.A. & Miller, A. 2000. A review of water quality concerns in livestock farming areas. Science of the Total Environment, 250(1–3): 143–167.

The organic and nutrient load of manure (Table 7.9) can consume significant amounts of oxygen in the water body (Table 7.10). Pathogens from livestock waste that are detrimental to public health include bacteria such as *Campylobacter spp.*, *Escherichia coli* O157 (see above), *Salmonella spp.* and *Clostridium botulinum*, and *parasitic protozoa* such as *Giardia lamblia*, *Cryptosporidium parvum* and *Microsporidia spp.*, all of which cause hundreds of thousands of infections every year (Christou, 2011). Figure 7.4 shows the common pathways of microbial water contaminants (Hooda *et al.*, 2000).

Table 7.9. Major nutrients in typical livestock waste

Source	Total nutrients (available fraction in parentheses)		
	N	P	K
	Solids (kg/t)		
Cattle FYM (25% DM)	6 (1.5)	3.1 (0.78)	5.80 (3.48)
Pig FYM (25% DM)	6 (1.5)	2.62 (1.53)	3.31 (2.90)
Broiler litter (60% DM)	29 (10.0)	9.60 (5.67)	13.27 (9.95)
	Slurry (kg/m^3)		
Cattle Slurry (6% DM)	3 (1.0)	0.52 (0.26)	2.98 (2.49)
Pig Slurry (6% DM)	5 (1.8)	1.31 (0.65)	1.99 (1.65)

Note: DM: dry matter; FYM: farmyard manure.

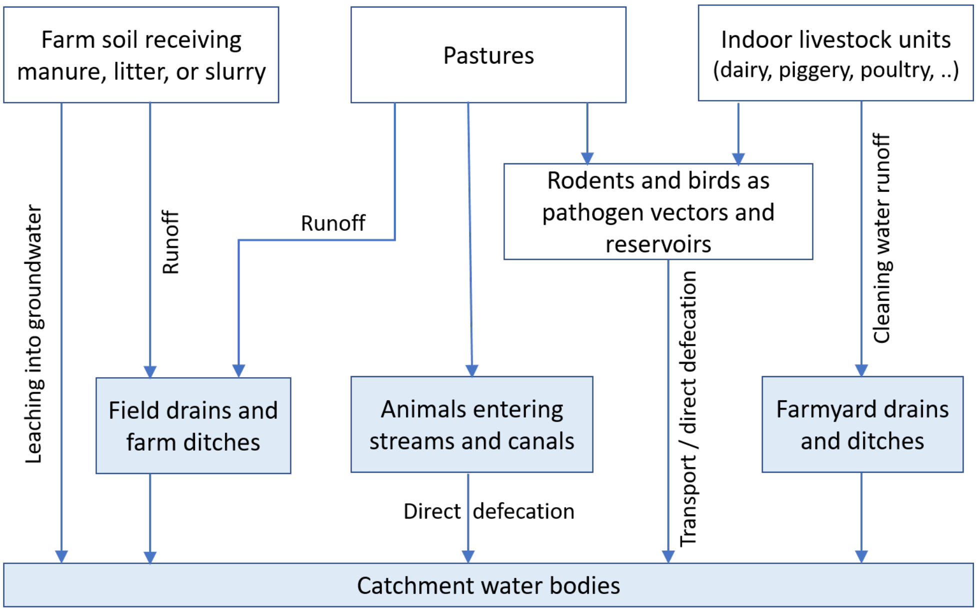
Source: Hooda, P.S., Edwards, A.C., Anderson, H.A. & Miller, A. 2000. A review of water quality concerns in livestock farming areas. Science of the Total Environment, 250(1–3): 143–167, after Webb, J. & Archer, J.R. 1994. Pollution of soils and watercourses by wastes from livestock production systems. In I. Ap Dewi, R.F.E. Axford, I.F.M Marai & H. Omed, eds. Pollution in livestock production systems, pp. 189–204. Wallingford, UK, CAB International

Table 7.10. Ranges of biological oxygen demand (BOD) concentrations for various waste types

Source	BOD (mg/L)
Silage effluents	30 000 - 80 000
Pig slurry	20 000 - 30 000
Cattle slurry	10 000 - 20 000
Liquid effluents draining from slurry stores	1000 - 12 000
Dilute diary parlour and yard washing (dirty water)	1000 - 5000
Milk	140 000
Untreated domestic sewage	300 - 00
Treated domestic sewage	20 – 60
Clean river water	< 5

Source: Hooda, P.S., Edwards, A.C., Anderson, H.A. & Miller, A. 2000. A review of water quality concerns in livestock farming areas. Science of the Total Environment, 250(1–3): 143–167, after Webb, J. & Archer, J.R. 1994. Pollution of soils and watercourses by wastes from livestock production systems. In I. Ap Dewi, R.F.E. Axford, I.F.M Marai & H. Omed, eds. Pollution in livestock production systems, pp. 189–204. Wallingford, UK, CAB International.

Figure 7.4. Pathways of catchment water contamination with microbial and protozoan micro-organisms



Source: Hooda, P.S., Edwards, A.C., Anderson, H.A. & Miller, A. 2000. A review of water quality concerns in livestock farming areas. Science of the Total Environment, 250(1–3): 143–167.

7.2.1. Good management practices to prevent water quality impacts from livestock

Given the high risks involved in compromised water quality, good management practices should be developed to safeguard the health of animals and their environment as well as downstream water sources.

As part of good practices in farm management, it is essential to comply with regulations concerning restrictions on animal movements and stocking rates, and consider the following practices to minimize negative impacts from livestock farming on the environment, in particular the quality of water sources in direct farm proximity:

- Study the landscape and context of the livestock production system to ascertain all the resources needed, in particular the water quality upstream and downstream of the farm or grazing area, the depth of shallow groundwater, the soil texture and infiltration rate. The objective is for the water downstream of the farm to have at least the same quality as the water upstream (i.e. zero negative impact).
- Determine the pollution pathways (see Figure 7.3 and Figure 7.4) of highest probability and the related critical control points for risk monitoring and mitigation.
- Implement measures to reduce farm runoff and leaching (see Chapter 8; ecology), and treat runoff from point pollution sources (e.g. through constructed wetlands) before the waste stream enters off-farm water bodies.

Selected best management practices for livestock safety are described by Hooda *et al.* (2000) and FAO & OIE (2009), among others.

7.3. Conclusion

This chapter describes how poor water quality can affect livestock, and how poor livestock management can affect water quality. It shows how impacts from farming can extend beyond the farm and reasons that such impacts are the responsibility of the farmer. However, as livestock systems differ significantly between animals, it is important to seek advice from extension officers regarding the most appropriate options to safeguard animal and environmental health. While this chapter has focused on low-cost management practices, any option must consider local feasibility and cost-effectiveness. Providing farmers with related guidance is the core task of government authorities and their extension services, local academia and international organizations, who must ensure that access to knowledge, risk awareness, and the capacity to adopt good practices to achieve good water quality management, is available to all types of livestock holders.

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