Chapter 12 - WATER QUALITY

Contents

A. Introduction

Water is the most important nutrient for poultry. In addition to being a nutrient, water also softens food and carries it through the body, aids in digestion and absorption, and cools the body as it evaporates through the bird's lungs and air sacs. Water helps remove waste, lubricates joints, is a major component of blood, and a necessary medium for many chemical reactions that help form meat and eggs.

Although water is regarded as the most essential nutrient, it is impossible to state its exact requirement. Under normal conditions, chickens will consume, by weight, *approximately* twice as much water as food. During periods of extreme heat stress, water requirements may easily quadruple. Table 12.1 indicates the typical quantities of water required for various poultry species and age.

Table 12.1 - Approximate water consumption for poultry (gallons/100 birds/day)

Type of poultry	Normal ambient temperature (68°F/20°C)		Hot weather (89.6°F/32°C)
	Average (growing)	Mature birds	Mature birds
Layer pullets	2.64	3.43	5.28
Breeder pullets	3.17	4.23	6.60
Layer hens		5.55	10.57
Broiler breeders		7.93	15.85
Broiler chickens	4.23	6.60	13.21
Roaster chickens	5.28	7.93	15.85
Broiler turkey	7.66	14.27	26.42
Heavy female turkeys	10.04	16.91	31.70
Heavy male turkeys	14.53	26.42	47.55

Adequacy of a water supply is typically evaluated in terms of how many **gallons per minute** (gpm) it can deliver on a sustained basis. A typical 500-ft broiler house requires about 2 gpm for drinking water, so a 5-house complex would require a 20-gpm water supply, just for drinking water for the broilers. For comparison, a well for a single-family residence is usually judged to be adequate if it can deliver around 4-5 gpm.

Evaporative cooling systems, using either foggers or pads, typically require about 8 gpm per house, which will up the total water requirement per house to 10 gpm. Recirculating pad systems are more efficient in water use than non-recirculating types, in that water not evaporated is 'recycled' and not lost. However, with either type system, almost all the water will be evaporated into the air going into the house during peak hot weather demand times, so the design gpm requirement will be the same no matter which type evaporative cooling system is used.

B. Evaluating water quality

When water looks clear and tastes okay, water quality is easy to take for granted. However, water quality is impossible to judge adequately except with ***laboratory testing***. Field experience has conclusively shown that unobservable differences in water quality, from farm to farm and even from one well to another within a complex, can result in significant differences in bird performance.

Drinking water should be clear, tasteless, odorless, and colorless. As a general observation, a ***reddish-brown color may indicate the presence of iron***, while a ***blue color indicates the presence of copper***. Hydrogen sulfide is indicated by a rotten egg odor. Hydrogen sulfide may also combine with iron to form black water (iron sulfide) that may also implicate the presence of sulfate-reducing bacteria. Taste can be affected by the presence of salts, and a bitter taste is usually associated with the presence of ferrous and manganese sulfates.

Water quality attributes can have a direct or indirect effect on performance. Poor water quality can retard growth, curtail egg production, or produce lower egg quality. Feed conversion, for example, has been positively correlated to the presence of sulfate and copper concentrates in the water, and livability with potassium, chloride, and calcium. Body weight is positively influenced by water hardness and dissolved oxygen and negatively influenced by total bacteria and a pH less than 6.0. While several elements can cause poor water quality, the interaction between elements is more significant in water quality problems than the simple fact of their presence. Table 12.2 lists the standards for water quality for poultry use.

Table 12.2 - Drinking water quality guidelines for poultry.

Contaminant or characteristic	Level considered average	Maximum acceptable level	Remarks
Bacteria			
Total bacteria	0/ml	100/ml	0/ml is desirable
Coliform bacteria	0/ml	50/ml	0/ml is desirable
Nitrogen compounds			
Nitrate	10 mg/l	25 to 45 mg/l	Levels from 3 to 20 mg/l affect performance.
Nitrite	0.4 mg/l	4 mg/l	
pH	6.8 to 7.5	----	A pH of less than 6.0 is not desirable. Levels below 6.3 may degrade performance.
Total hardness	60 to 180	----	Hardness levels < 60 are unusually soft; those > 180 are very hard.
Naturally occurring chemicals			Levels as low as 14 mg/l may be detrimental if the sodium level is higher than 50 mg/l.
Calcium	60 mg/l	----	
Chloride	14 mg/l	250 mg/l	
Copper	0.002 mg/l	0.6 mg/l	Higher levels produce a bad odor and taste.
Iron	0.2 mg/l	0.3 mg/l	Higher levels produce a bad odor and taste.
Lead	----	02 mg/l	Higher levels are toxic.
Magnesium	14 mg/l	125 mg/l	Higher levels have a laxative effect. Levels > 50 mg/ml may affect performance if magnesium and chloride levels are high.
Sodium	32 mg/l	----	Levels above 50 mg/l may affect performance if the sulfate or chloride level is high.
Sulfate	125 mg/l	250 mg/l	Higher levels have a laxative effect. Levels >50 mg/l may affect performance if magnesium and chloride levels are high.
Zinc	----	1.50 mg/l	Higher levels are toxic.

Source: Adapted from T.A. Carter and R.E. Sneed, *Drinking water guidelines for poultry*. Poultry Science and Technology Guide No. 42, North Carolina State University

Bacteria

The presence of microorganisms is typically a result of surface contamination by organic minerals and can result in poor performance. The presence of coliform bacteria is generally related to fecal contamination of drinking water due to runoff to surface or ground waters. Ideally, bacterial contaminants should not be present in drinking water and measurable levels should be zero.

The first step towards eliminating contamination is to determine if the source is the well or the distribution system. Samples taken for bacterial testing should be obtained in a sterile manner and may need to be taken at the source and at strategic points to localize any problems.

Chlorination or **filtration** of the water supply can eliminate bacterial contaminants. For a properly sealed and located well, treatment of the well cavity with a chlorine source such as sodium hypochlorite may remedy the problems. If continuous chlorination seems necessary, it should be applied gradually. Between two and five ppm of residual chlorine is recommended. Start at the lower concentration and increase it until control is satisfactory. Since water intake is the most sensitive criteria, it should be monitored during this process for signs of intolerance. Long term correction may require well sealing or re-siting. Chlorine levels in the water can also be monitored using a pool test kit.

A common water quality problem in the Southeast U.S. is **excess iron**, along with bacteria that feed on the iron and form a reddish brown slime that clogs filters, drinkers and fogger nozzles. Mild **iron bacteria** problems can often be dealt with by 'shock chlorination,' which involves a one-time treatment between flocks, injecting a strong chlorine solution into the well and circulating and flushing it through all pipes in the system. For more severe iron bacteria problems, continuous chlorination is called for, installing a 'chlorinator' to continuously inject chlorine into the water system. Chlorine not only kills bacteria but is an oxidizing agent, meaning it causes minerals such as iron and manganese to combine with oxygen, in the process coming out of solution and forming a solid precipitant. Because of this reaction, a sand media filter must be installed downstream from the chlorinator to remove the mineral solids from the water. Chlorination also prevents other kinds of bacterial contamination, and may be needed even if iron and iron bacteria are not present in the water supply.

Use of an **iodine-base disinfectant** to control bacteria in drinking water is effective and provides more residual activity but is usually more expensive than chlorination. Be sure to use only approved chemicals at the recommended rates and ensure that the chemicals are compatible with watering equipment. Also, be sure to remove the disinfectant from the waterers and water lines before using a water vaccine or medication that is incompatible with the disinfectant.

Nitrogen compounds

Nitrates (NO_3) are produced during the final stage of decomposition of organic matter. Their presence in water usually indicates contamination by runoff containing fertilizer or human and animal wastes. Nitrates are soluble and may move with surface runoff or leach into the groundwater by percolation through the soil. Nitrates from sources such as animal and human wastes, nitrogen fertilizer, crop residues, and industrial wastes may move considerable distances in the ground. **Nitrite** (NO_2) is produced during intermediate stages of the decomposition of organic compounds.

The toxicity of nitrates to poultry varies with the age of the birds, older birds being more tolerant. Research with commercial broilers have shown that nitrate levels greater than 20 mg/l have a negative affect on weight, feed conversion, or performance. Levels between 3 and 20 mg/l are suspected to affect performance. **Nitrites are toxic at much lower levels than nitrates**; concentrations as low as 1 mg/l can be toxic.

Nitrate itself is not toxic. After ingestion, however, it is converted to the toxic form of nitrite by microorganisms found in the intestinal tract of the bird. Once absorbed into the bloodstream, **nitrite binds strongly to hemoglobin** and, thereby, reduces the oxygen carrying capacity of the blood. Chronic nitrate toxicity causes poor growth, anorexia, and poor coordination. Students demonstrate that nitrate nitrogen levels in the drinking water as low as 3 to 5 mg/l depress broiler growth rate.

Well-drilling techniques have improved since many of the older, shallow wells were constructed. If nitrate or nitrite levels in your well water are too high and you cannot eliminate the source of contamination, drilling a new or deeper, properly constructed well may solve the problem.

Nitrate is a very soluble substance, easily dissolved in water and extremely hard to remove. **Treatment for nitrate** is, therefore, very complicated and expensive. The three methods of reducing or removing nitrate are:

- Demineralization by distillation or reverse osmosis
- Ion exchange
- Blending

Demineralization removes nitrate and all other minerals from the water. **Distillation** is one of the oldest, most effective types of demineralization. The distilling process has only three steps:

1. The water is boiled;
2. The resulting steam is caught; and
3. The steam is condensed on a cold surface, turning back into water.

The nitrate and other minerals remain concentrated in the boiling tank.

Reverse osmosis is another way to de-mineralize water. It reduces but does not remove all nitrates. In a reverse osmosis system, the water is put under pressure and forced through a membrane that filters out minerals and nitrate. One-half to two-thirds of the water remains behind the membrane as rejected water. The yield of treated water to reject water is related to the amount of pressure applied; the lower the water pressure, the greater the volume of reject water. Higher-yield systems use water pressures in excess of 150 psi. The systems that operate using standard household water pressure (35 to 45 psi) will yield some treated water, but a large amount of untreated water goes down the drain, and could reduce the efficiency of home septic systems. Household units are usually small enough to fit under the sink or on a kitchen counter.

Both of these demineralization systems ***require a lot of energy to operate efficiently and are high-maintenance systems***. They are also low-yield systems that may provide enough water for a family, but cannot produce the large quantities needed for livestock.

The second type of water treatment for nitrate contamination is ion exchange**. Ion exchange** introduces another substance that trades places with the nitrate. Most often chloride is exchanged for nitrate. The ion exchange unit is a tank filled with special resin beads that are charged with chloride. As water containing nitrate flows through the tank, the resin takes up nitrate in exchange for chloride. In time, all the chloride will be exchanged for nitrate. The resin can then be recharged by back washing with a brine solution (sodium chloride) and reused.

Because ion exchange systems can treat large volumes of water, they are more appropriate than demineralization for treatment of livestock water supplies. There are, however, some drawbacks to ion exchange systems. First, in addition to exchanging nitrate, the resin beads will also take up sulfate in exchange for chloride. Therefore, if sulfates are present in the water supply, the capacity of the resin to take up nitrate is reduced. Second, the resin may also make the water corrosive. For this reason, the water must go through a neutralizing system after going through the ion exchange unit. Finally, **backwash brines**, which are high in nitrate, must be disposed of properly so they do not re-contaminate the groundwater supply.

The third and most common way to reduce nitrates is to dilute the nitrate-polluted water by blending it with water from another source that has low nitrate concentrations. **Blending the two waters** produces water that is low in nitrate concentration. Blended water is not safe for infants but is frequently used for livestock.

There is no simple way to remove all nitrates from your water. Although it is common to think of boiling, softening or filtration as a means of purifying water, none of these methods reduce nitrate contamination. ***Boiling water is, in fact, the worst thing to do because it actually concentrates the nitrate***. Softening and filtration do nothing at all to remove nitrate.

pH

The acidity or alkalinity of water is measured by pH. A pH of 7 indicates that the water is neutral, a pH less than 7 indicates **acidity**, and a pH greater than 7 indicates **alkalinity**. Low pH water can be unpalatable, corrosive to equipment, and may have a negative impact on performance. High pH water is also unacceptable since it reflects high levels of calcium and magnesium, which can clog watering systems. Poultry accept water on the acid side better than they accept water on the alkaline side.

Hardness

Hardness refers to the presence of dissolved minerals such as calcium and magnesium in either bicarbonate or sulfate form and is **expressed as an equivalent of calcium carbonate**. It measures the tendency of water to precipitate soap and form scale. Hard water is commonly associated with the buildup of deposits and the formation of scale in the components of the watering system. Hardness is not commonly harmful to poultry unless certain ions are present in toxic amounts. High levels of magnesium sulfate ($MgSO4$) may cause an increase in water consumption, wet droppings, and a drop in production. Iron, aluminum, and zinc can also contribute to hardness and should be considered if present in unusual amounts. Extreme hardness may diminish the effectiveness of water-administered medications, disinfectants, and cleaning agents.

Hardness should not be confused with salinity. Water can be very soft with low levels of calcium and magnesium, yet have a high salinity value from dissolved sodium salts. Most ground waters have hardness values of less than 2000 mg/l (may be higher in arid areas). Occasionally, hardness is reported as grains per gallon (1 grain per gallon is equivalent to 17.1 mg/l). Water hardness has been classified as follows:

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

When hard water is a problem in proper equipment operation, it can easily be ‘softened’ with commercial water treatment equipment. Most of the processes exchange the sodium ion from sodium chloride for other minerals present. It is recommended that the sodium of softened water be monitored because it may influence the amounts of fish meal, defluorinated phosphate, bakery products or salt used by your nutritionist.

Salinity

Salinity refers to salts dissolved in water. The **anions** (negatively charged ions) commonly present include: carbonate, bicarbonate, sulfate, nitrate, chloride, phosphate, and fluoride. The **cations** (positively charged ions) include calcium, magnesium, sodium and potassium.

Salinity may be measured as Total Dissolved Solids (TDS) or Total Soluble Salts (TSS) and is expressed as parts per million (ppm) which is equivalent to milligrams per liter (mg/l) or micrograms per milliliters (µg/ml). Salinity may also be measured by electrical conductivity and is then expressed as reciprocal micro ohms per centimeter (omhos/cm) or decisiemens per meter (dS/m).

Salinity by itself tells nothing about which elements are present, but this may be of critical importance. So when the salinity is elevated, the water should be analyzed for the specific anions.

Total Dissolved Solids

Measurement of total dissolved solids (TDS), or salinity, indicates levels of inorganic ions dissolved in water. Calcium, magnesium, and sodium salts are the primary components that contribute to TDS. High levels of TDS are the most commonly found contaminants responsible for causing harmful effects in poultry production. Table 12.3 provides guidelines suggested by the National Research Council for the suitability for poultry water with different concentrations of total dissolved solids, which are the total concentration of all dissolved elements in the water.

Table 12.3 - Suitability of water with different concentrations of Total Dissolved Solids (TDS)

TDS (ppm)	Comments
Less than 1,000	These waters should present no serious burden to any class of poultry.
1,000 to 2,999	These waters should be satisfactory for all classes of poultry. They may cause watery droppings (especially at higher levels) but should not affect health or performance.
3,000 to 4,999	These are poor waters for poultry, often causing watery droppings, increased mortality, and decreased growth.
5,000 to 6,999	These are not acceptable waters for poultry and almost always cause some type of problem, especially at the upper limits, where decreased growth and production or increased mortality probably will occur.
7,000 to 10,000	These waters are unfit for poultry but may be suitable for other livestock.
More than 10,000	These waters should NOT be used for any livestock or poultry.

Source: National Research Council. 1974. Nutrients and toxic substances in water for livestock and poultry. National Academy of Sciences, Washington, DC

Mineral contaminants

A wide variety of minerals are commonly found in drinking water. Normally, they are found in relatively low concentrations and cause no harm (see Table 12.2).

High concentrates of **sulfates** can combine with **magnesium** to form Epsom salt or with **sodium** salts that cause a laxative effect and can result in wet litter. High concentrations of sodium or chloride may also increase water consumption and increase litter moisture. High levels of sulfate may also interfere with the intestinal absorption of other minerals such as copper.

High levels of magnesium are only a problem in the presence of high sulfate levels since they combine to form Epsom salt. The formation of scale in the watering system can be attributed to high levels of or combinations of sulfate, magnesium, or calcium.

High levels of **iron** may encourage the growth of bacteria, which can lead to diarrhea. When the ferrous form of iron present in well water is exposed to the air, it is converted to the ferric hydroxide form commonly referred to as rusty water.

Other contaminants in the water may include **pesticides**, **herbicides**, **industrial residues**, **petroleum products**, and **heavy metals** such as lead or cadmium. Such contaminants are more difficult to detect and require more costly testing procedures.

Turbidity

Turbidity results from the suspension of materials such as **silt**, **clay**, **algae** or **organic materials** in water. Levels of turbidity above 5 ppm result in unpalatable water and indicate surface contamination. Turbid water can be filtered to remove particular contaminants and prevent clogged water lines.

C. Water management

- **Conduct water tests.** Each farm should have its well water tested. Water quality can change during periods of heavy rain or drought, and additional water tests during these periods will ensure that water lines continue to deliver adequate water volume for both the birds and the cooling systems.

- **Change filters regularly.** Sediment and other particulates can cause leaky water nipples that can have negative effects on litter quality. Clogged filters restrict water flow to the drinker and cooling systems. In some cases, simple cartridge filters may not be adequate, such as for water with high iron. In those cases, consider other water treatments.

- **Flush water lines regularly.** Perform a high pressure flush on water lines between each flock and after adding supplements through the medicator (i.e., vaccine, medications, vitamins, electrolytes, etc.).

- **Plan ahead before treating water.** Before implementing water treatment or sanitation programs, consult your county agent to be sure contaminants in your water will not react negatively and cause the water system to become clogged.

D. Water treatments

Various methods are available that can reduce or eliminate the impurities that adversely affect water quality.

Chlorination

Chlorination is the most common method used to treat water for bacterial contamination and effectively eliminate bacteria from the water supply. Chlorine can be administered through an in-line proportioner. General recommendations are to have a level of 2 or 3 ppm at the drinker farthest from the proportioner. Chlorine levels can be easily monitored using a pool test kit.

Softeners

Use water softening equipment to reduce hardness. Most softening equipment uses ion exchange to effectively remove the calcium and magnesium ions and replace them with sodium ions. Levels of TDS, however, are simply substituted and increases in sodium concentration of the water occur, possibly to unacceptable levels. Poultry are generally sensitive to increases in sodium levels, so producers should be judicial in their selection and use of water softening equipment.

Polyphosphates

Polyphosphates are chemical compounds used primarily to prevent the buildup of scale in the watering systems. They act to cause mineral contaminants to go into solution more readily.

Electrical/Magnetic devices

Electrical or magnetic devices keep minerals associated with scale buildup in solution by altering their electrical charges.

Guidelines for chlorination

- Do not chlorinate market age birds under extreme heat stress.
- Measure residual chlorine at the waterer to maintain at least a 1.0 ppm level at the drinker mid-house.
- Discontinue chlorination and administer powdered milk solution before vaccination to neutralize chlorine since chlorine kills vaccines.
- Use caution since chlorine solutions are acidic and often oxidize soft rubber.

E. Water temperature

Drinking water temperatures should be between 50°F to 60°F (10°C to 15°C) for the most comfortable consumption by mature birds, but some studies have indicated that water temperatures of about 77°F (25°C) reduce mortality in chicks and poults. Temperatures over 86°F (30°C) will reduce consumption and birds will refuse to drink if water temperatures are over 111°F (44°C).