Chlorinating drinking water on poultry farms

Chlorination of drinking water on poultry farms minimizes the level of microorganisms and also prevents or minimizes the formation of biofilm. It may also help retard the spread of the infectious agents through contaminated water in the drinkers. But a thorough understanding of its application is needed.

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Chlorination of drinking water on poultry farms is a relatively common practice to minimize the level of microorganisms, especially bacteria, thus providing the birds with hygienic water. This is especially important when the source of drinking water on the farm is not hygienic. Chlorination of the drinking water also prevents or minimizes the formation of biofilm (an aggregate of microorganisms surrounded and adhered to a surface by a slime substance) in the water distribution system that may be difficult to clean between flocks. In addition, biofilm can be a potential source of harmful bacteria in the drinking water. Also, in the event of a disease outbreak, chlorination of the drinking water may help slow down the spread of the infectious agents in the poultry house through contaminated water in the drinkers.

Chlorine and chlorine-releasing compounds

Chlorine (Cl_2) is a strong oxidizing agent and a potent sanitizer that is widely used to sanitize drinking water on poultry farms. It is very effective against gram-positive and gram-negative bacteria, enveloped and non-enveloped viruses, mycoplasmas, and protozoa. Bacterial and fungal spores are less susceptible, and higher levels of chlorine are required to destroy them completely. The oocysts of *Eimeria* (coccidia) and *Cryptosporidium* are resistant to chlorine. In very simplified words, chlorine kills microorganisms by oxidizing them, thus altering the chemical structure, and consequently disrupting the integrity and normal function of the cell. The contact time required to kill microorganism depends primarily on the type of the microorganism, the concentration of chlorine, and the temperature of the solution.

The most widely used chlorine-releasing compound is sodium hypochlorite (NaOCl) (household bleach), which is a greenish-yellow liquid available commercially in different concentrations of NaOCl. Another chlorine-releasing compound is trichlor (trichoro-s-triazinetrione), which contain about 90% available chlorine and is available as tablets that dissolve very slowly in cool water and release chlorine over a period of time. Chlorine gas is the purest form of chlorine with available chlorine content of 100%, but although it is available as sanitizer, it is extremely dangerous and restricted in its use. NaOCl is very alkaline (pH 13) and will increase the pH of the solution, while trichlor and chlorine gas lower the pH of the solution.

Reaction of chlorine water

In order to understand how chlorine works, it is necessary to know what happens when a chlorine-releasing compound is added to the water. When added to the water, a chemical reaction occurs and results in the formation of hypochlorous acid (HOCl). HOCl is a weak acid and further dissociates to form hypochlorite ion (OCl^-). Both HOCl and OCl^- are referred to as the "free chlorine", "free available chlorine" or "free residual chlorine". However, it is very important to know that HOCL is much more efficient and faster than the OCl^- in killing a microorganism, thus it is called the active or killing form of the free chlorine. OCl^- is a weak sanitizer, probably because its negative charge creates an obstacle to penetrating the cell of the microorganism, and so it contributes very little to the sanitizing ability of chlorine. The dissociation of HOCl to OCl^- depends primarily on the pH (acidity) of the solution; in other words, the relative concentrations of HOCl and OCl^- are determined principally by the pH of the solution. *Table 1* shows the percentage of HOCl and OCl^- in a chlorine solution at certain pH values. At a pH of approximately 7.5 the concentrations of HOCL and OCl^- are roughly equal (about 50% of each). Under field conditions, keeping the pH of drinking water between 6.5 and 7.0 will be sufficient to ensure that most of the free chlorine is in the form of HOCl. But as will be discussed later, it should be realized that other factors could affect the

Figure 1 - A typical hand-held ORP meter.

availability of HOCl in the water in drinkers. HOCl also oxidizes certain soluble minerals such as iron, manganese, and hydrogen sulphide; it also reacts with organic matters, ammonia and other nitrogen-containing compounds. In the process of oxidation, HOCl is converted to chloride ion (Cl^-), which has no sanitizing effect. The conversion of HOCl to Cl^- is reversible and is pH driven. When HOCl reacts with ammonia or nitrogen-containing compounds in the organic matters, it forms chloramines, which are the "combined chlorine" or "combined available chlorine". Combined chlorine is considerably less effective in killing microorganisms than free chlorine. If the water distribution system (water pipes and drinkers) has biofilm, then the free chlorine will be used up before reaching the drinkers, especially those at the end of the house. Additionally, when HOCl reacts with the organic matters such as litter materials and feed particles that may be present in the drinkers, it will no longer available as free chlorine that can sanitize the water. This underscores the importance of thorough cleaning and disinfection of water distribution system between flocks to remove biofilm, and of daily cleaning of drinkers.

Measuring free chlorine

Poultry growers should routinely check the level of chlorine in the drinkers. Just because chlorine is dispensed into the water system does not necessarily mean there are enough levels in the drinkers, as several factors can affect the availability of free chlorine, especially HOCl.
Conventionally, colour-based test kits or paper strips are used to measure the level of chlorine in water in parts per million (ppm). It is important to use paper strips or a test kit that measure the free chlorine (HOCL *plus* OCl^-) and not the total chlorine (free chlorine *plus* combined chlorine). Some colorimetric test kit, for example, the orthotolidine colorimetric test, which is based on yellow-colour matching, measures both free and combined chlorine. A standard recommendation in the poultry industry for water sanitization is to aim at 2 to 3 ppm free chlorine in drinkers at the end of the house. Now, the issue becomes more complicated by the fact that HOCl is the free form of chlorine that is efficient in killing microorganisms. As mentioned before, the percentage of HOCl relative to the percentage of OCl^- is primarily determined by the pH of the water. From a practical standpoint, this really should not be a concern as long as the pH of the drinking water is between 6.5 and 7.0 to ensure that most of the free chlorine is in the form of HOCl (see the table above). If the pH is high (over 7.5), then it may be necessary to acidify the water. Remember that NaOCl is very alkaline and may increase the pH of the water. For acidification of the water, inorganic acids such as sodium bisulfate, or organic acid such as propionic acid, acetic acid, or citric acid can be used. It has been indicated that organic acids have strong taste associated with them, and may cause birds to consume less water.

Table 1 - Percentages of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) at certain pH values

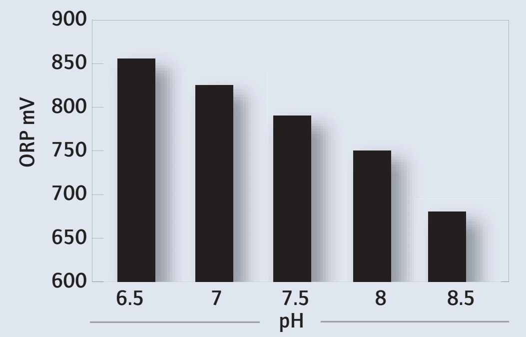
PH	% as HOCl	% as OCl^-
8.5	10	90
8	21	79
7.5	48	52
7	72	28
6.5	90	10
6	96	4
5	100	0

A better way to measure

Another way to measure the activity of chlorine is by measuring the "Oxygen-Reduction Potential" (ORP) (also known as Redox Potential) in the water. The ORP does not directly measure the level of free chlorine (or other oxidizing sanitizers) in the water, but rather indicates how much oxidizing activity (antimicrobial activity) is in the water. Remember that chlorine is an oxidizing agent, so the higher chlorine level in the water, the higher oxidizing activity and the higher ability to kill microorganisms.
The ORP in the water can be measured by using an instrument called ORP meter, which measures in millivolts (mV) the electrical potential in the water. As the oxidizing activity in the water increases, the ORP value goes up. A primary advantage of using ORP is that it provides the operator with a rapid and single-valued assessment of the sanitizing activity in the water. Another potential advantage of ORP is that it determines the activity of HOCl and not that of OCl^- or chloramines. OCl^- and chloramines have much lower ORP values than that of HOCl (the active form of chlorine), and for this reason, when HOCl is present it tends to mask the ORP of OCl^- and chloramines. Now, one can realize that changing the pH of a chlorine solution will change the ORP value. Lowering the pH will raise the ORP value as more HOCl is formed. Paper strips and color-based test kits that measure free chlorine detect both HOCl and OCl^-, and so changing the pH of a chlorine solution will not change test results (concentration in ppm).

Battery-operated, hand-held ORP meter are available and is easy to use (*Figure 1*). To ensure accurate and reliable testing results, it is extremely important to follow the manufacturers instructions regarding the maintenance and calibration of the instrument. It should be mentioned that a study has shown that in order to obtain a meaningful reading, the ORP meter should be immersed in the solution for minimum of about 10 minutes. It is also recommended to standardize a method of taking measurements with an ORP meter.

Figure 2 - The OPR values in water with 2 ppm free chlorine at a pH range of 6.5 to 8.5



Note that as the pH decreases, the ORP value increases

ORP values

So what is a good ORP value? Studies have shown that an ORP value of 650 mV or greater indicates that there is enough oxidizing activity in the water to kill most bacteria and viruses on contact or within seconds. One study has shown that in swimming pool water, *E. coli* is killed within seconds at an ORP value of 650 mV. In poultry houses, an ORP value between of 700-750 mV in the water in drinkers is recommended. There is really no need for ORP value greater than 750 mV. If the ORP value is high, then the amount of chlorine can be decreased. On the other hand, if the ORP value is low (below 650), then it can be increased by adding more chlorine or by lowering the pH of the water with water acidifier. As a general rule, maintain a balance between the amount of chlorine used and the pH of the water. Although birds can tolerate high levels of chlorine (around 10 ppm) in the drinking water, one should avoid a sudden, drastic increase as this can cause birds to back off drinking. And even though chlorine is most effective at a pH of 5.0 to 7.0 where HOCl is the predominant form, it is not recommended to lower the pH below 6.0, as it is generally believed that a pH of lower than 6.0 may decrease water intake. Also, at a pH below 5.0, the chlorine tends to dissipate in the air as chlorine gas, thus decreasing effectiveness and may cause damage to the silicon valves in the watering system.
Caution: Never mix acid and chlorine in concentrations, as this will rapidly generate toxic chlorine gas. The two solutions must be dispensed into separate ports in the water distribution system.

A frequently asked question is what are the correlations between the concentrations in ppm and the ORP values? This is difficult to answer because this correlation is pH dependent. In a chlorine solution with certain ppm free chlorine, the ORP value of the solution depends primarily on the pH. As the pH goes down, the ORP value goes up, and that is because more HOCl is present at lower pH (figure 2). Changing the pH will not change the concentration in ppm of free chlorine. ■