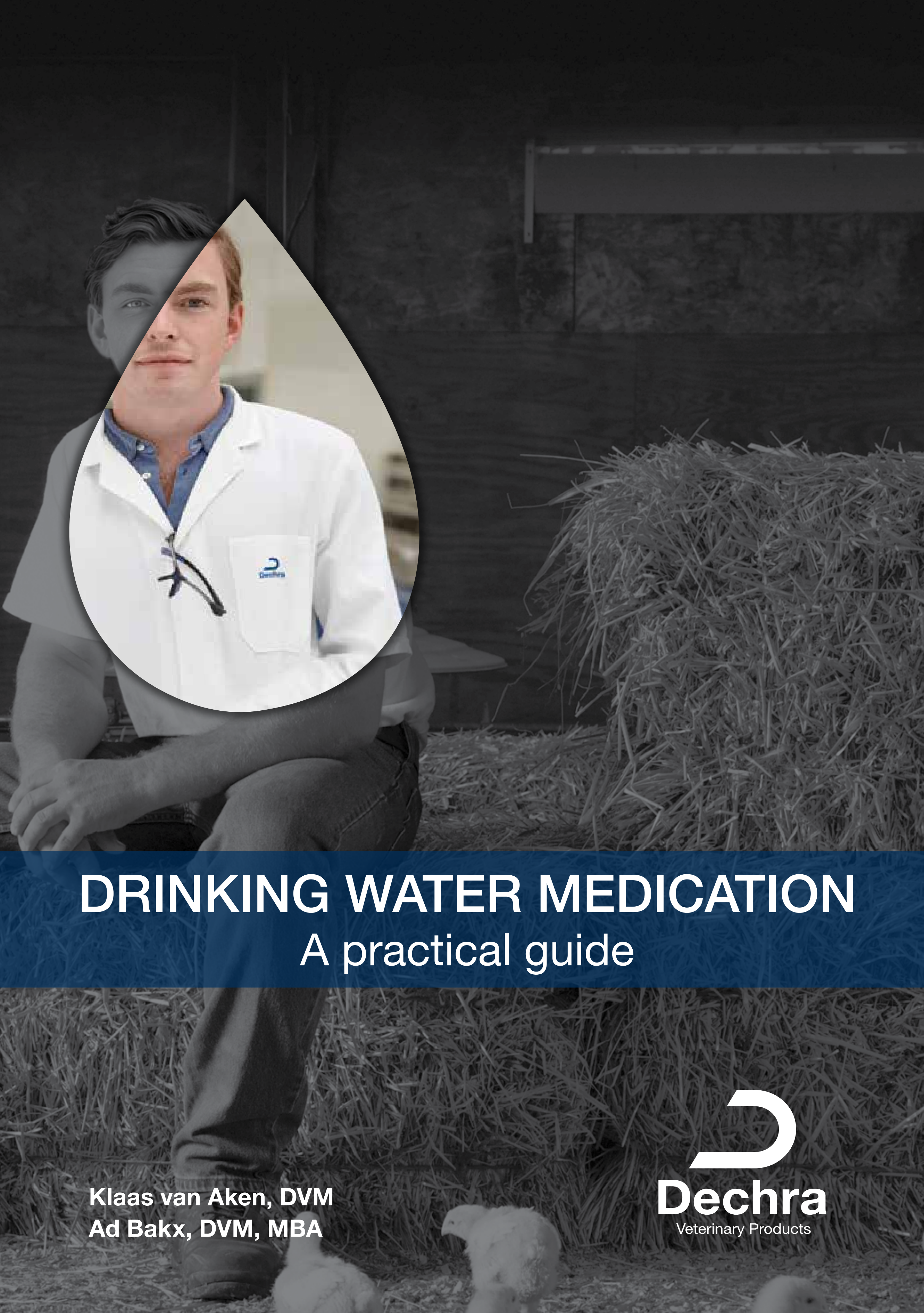

# DRINKING WATER MEDICATION

## A practical guide


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Dechra
Veterinary Products

## Preface

The primary focus of farm management is to prevent disease. However, if animals are unwell it is crucial to start treatment as soon as possible.

A treatment method that is being used more and more with increasing farm size is water medication. Water medication is relatively easy and has major advantages in terms of starting treatment within hours of a disease being detected, flexibility of administration and following the four principal rule of responsible use of antimicrobials:

1. Treat the right animals
2. At the right time
3. With the right antimicrobial
4. In the right dose

For drinking water medication you need products that dissolve well and that are stable once dissolved. With **SoluStab®** we offer a premium range of lactose free water-soluble products with a unique formula providing an optimal balance between solubility and stability.

By using **SoluStab®** products you can achieve the correct concentrations at drinking nipple level quickly, while reducing labor costs and waste and ensuring the swift recovery of the animals.

But it takes more than this for water medication to be successful.

- Firstly, the water has to be of good quality. Because numerous parameters can interfere with medication in many ways, it is crucial that all parameters meet the chemical and microbiological standards for good drinking water.
- Secondly, the drinking water system should be well-designed and properly maintained, cleaned and disinfected.

This guide is intended for professionals who in daily practice deal with water medication (veterinarians, farm managers and farm workers). It will help them to better understand the key factors for successful water medication and to optimize management practices.

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**Dechra Veterinary Products**

## Table of contents

**Notes on using the Dechra water medication and drinking water systems guide**

The aim of this guide is to provide veterinary professionals with a practically useful advice on drinking water quality, the use of drinking water systems and the behaviour of antimicrobials in drinking water. The advice contained in this guide is based on a combination of literature review, clinical experience and expert contribution. We do not claim that this advice is necessarily “correct” or that it deserves greater prominence than guidance provided by other professional bodies or special interest groups. This guide is provided solely for informational purposes and is intended for use by veterinary professionals with regard to treatment of animals only.

Please note that while we have endeavoured to make sure all quoted doses are correct, users of this guide should always consult statutory texts and read the prescriptions of the products used. Furthermore, they should bear in mind that the content of this guide is based on information available to us up to July 1st, 2012. It is therefore possible that advice contained in this guide will become outdated as more research is conducted and published.

No liability is accepted for any injury, loss or damage, however caused.

## Introduction

Water is important for regulating body temperature, growth and production, and for transporting nutrients and waste products within the body. To ensure good health and production levels, animals must have access to good quality drinking water.

Problems such as clogged drinking nipples and piping after administering antimicrobials usually indicate that the quality of the water in the well or the stable is poor.

Drinking water from the water company always meets the quality requirements. When a livestock breeder uses water from a well, the chemical and bacteriological properties of the water should be tested at least once per year.

In addition to contamination of the water in the well, water can be contaminated due to inadequate hygiene in drinking troughs, piping and float tanks. Hence, it is important, in addition to testing the water quality of the well itself, to also test the water quality at drinking locations, in piping and float tanks at least once per year. Also important are a thorough analysis of the drinking water system and an inventory of all drinking water supplements used until the last time the drinking water system was cleaned.

This guide covers three topics:

**Part I: 'Water quality'** stresses the importance of clean drinking water and covers amongst other sugjects water testing. An explanation is given of where the water samples should be taken and how the results of the water testing should be evaluated.
Solutions are then suggested for various problems.

**Part II: 'Drinking water systems'** explains the analysis of drinking water systems.
The entire drinking water system is thoroughly examined using flowchart diagrams.
Solutions for the various problems are presented, and a description is given of the best way to clean and maintain drinking water systems.

**Part III: 'Antimicrobials'** describes the behaviour of antimicrobials in drinking water.
The advantages and disadvantages of administering antimicrobials via drinking water are treated, as are the interactions between pharmaceutical antibiotic preparations and water parameters.

This step-by-step plan aims to give you specific advice on how to remedy and prevent problems with drinking water and drinking water medication. In result, animals should recover earlier, being both of economical and ethical benefit.

# PART I DRINKING WATER QUALITY

# 1. Introduction

Drinking water quality is often taken for granted. While quality is certainly good in the case of tap water, the costs of maintaining this quality are increasing yearly. More and more livestock breeders are using their own sources of drinking water for their livestock, i.e. they are extracting water from the ground.

There are no legal criteria in Europe for determining the quality of drinking water for livestock. Drinking water quality, however, must meet specific criteria since animal products intended for human consumption are subject to specific requirements. Substances in the drinking water have an indirect influence on animal products intended for human consumption.

The taste of drinking water is important for good water intake. This requires the water to have good chemical and bacteriological properties. Iron ($Fe > 10$ mg/l) or salt ($Na > 400$ mg/l) levels that are too high can affect the water's taste causing the animal's water intake to be reduced. Decreased water intake can lead to reduced feed intake, and thus to **decreased yield. Especially young animals** learning to drink water are very sensitive to the taste of water.

The safety of water is assessed based on its chemical and bacteriological properties.

Chemical assessment includes:

- Nitrogen components (ammonium, nitrite and nitrate)
- Salts (sodium, chloride, sulphate)
- Minerals (calcium and magnesium = water hardness)
- Metals (iron and manganese)

The bacteriological assessment includes the total bacterial count and the number of coliform bacteria.

Animals must have adequate access to drinking water. For drinking water via drinking nipples, the height of the drinking **nipples, the number of animals per drinking nipple, the water flow rate per nipple and the accessibility of drinking nipples are important.**

## 2. Groundwater and tap water

The first step in finding the cause of livestock drinking water problems is determining whether a farm is using groundwater or tap water as drinking water for the livestock. If a farm makes use of water from a well, the type of purification plant used must be determined.

Water from wells (groundwater) does not always meet the quality requirements. A possible cause of bad water quality from the well is poor well construction.

If the well is poorly constructed or if the ammonium level of the groundwater is too high, the livestock breeder is advised to connect to the public water system or to have a new well drilled. Sometimes water quality can be improved by making the well deeper or shallower.

Note
Drinking water from the water company is preferred, since it always meets the quality requirements. Contamination of tap water can only occur in the animal housing as a result of inadequate hygiene in float tanks, piping and drinking troughs. Have the chemical and bacteriological properties of well water checked at least once per year.

**Purification systems**

If a farm uses well water, the water must be purified using a purification system.
The type of purification plant depends on the parameters that must be removed from the water.

Possible purification systems on a farm include;

- Water softeners
- Deferrization installations
- Reverse osmosis installations

More information on these installations can be found in appendix 1 *Description of different purification processes for drinking water* and in appendix 2 *The purification process per parameter*.

Note
Have the purification installation inspected by a specialist at least once per year.

## 3. Drinking water test

The second step in locating the cause of problems in drinking water is testing the quality of the drinking water at various locations in the drinking water system.

The water samples taken must be subjected to a chemical test *:

- Well water **

The water samples taken must be subjected to a bacteriological test:

- Well water
- Water in the stable (piping)
- Water at the place where animals drink

* Chemical water testing in the stable and at the place where the animals drink is unnecessary, since it is accepted that water parameters (except for bacterial count) do not change much after leaving the well.

** When testing the drinking water from wells, a water sample should be taken from the first regularly used tapping point, immediately after the filters of the purification installation. Drinking water from water companies does not require chemical or bacteriological testing where it enters the stable, since it can be assumed that the quality of tap water is reliable.

The different drinking water tests are described in appendix 3 *Available drinking water tests*.

The locations where water samples are taken for bacteriological testing depend on the type of farm and the problem being addressed. Often no more than three different water samples are taken. A number of guidelines are provided below for taking water samples to be used for bacteriological testing:

1. When using float tanks on a farm, a sample must be taken from a float tank located at the end of a drinking water system, preferably a float tank located in the section and/or in a warm location. Place the closed sample container under water and loosen the lid under water. Allow the container to fill and then re-close the container under water. This prevents a sample being taken of the dust layer on the surface of the water.

2. Water samples from a drinking water point in the piglet/pig section. A sample from a drinking nipple/drinking trough should be taken from a section that obtains water from float tanks. Always take the last nipple/drinking trough in the piping system. Preferably from a section with low water flow and a high temperature (for example, recently weaned piglets/recently penned pigs). If it is not possible to take a sample directly from the nipple, disconnect the piping from the last nipple and collect the first 1 to 3 litres in a clean (white) bucket, and then take the sample from this.

3. If medication was recently administered to the pigs via the drinking water, it is recommended to also take a sample from this section. Again, take the sample from the last nipple. Indicate on the laboratory form how many days the animals no longer received medication via the water, and the medication that was last administered.

4. The quality of the drinking water in gestation crates is of major importance. The nipple for the sow is used almost continuously, while the nipple for the pigletis only used approximately ten days after birth. Four to seven days after the birth of a litter, take a sample from the nipples in the gestation crate intended for the piglets. Here again it is best to choose a nipple as far as possible into the drinking water system. By way of comparison, a sample can be taken from a nipple for the sow in the same gestation crate.

5. In the sickbay, the risk of infection is high and the flow of water minimal.

6. Many organisms grow in stagnant water, so an empty section can provide interesting water samples.

In addition to the obligatory test of the existing well, a study can be done based on problems and complaints.

Bacteriological testing of the water twice per year can reveal problems in time to deal with them effectively.

Note
In addition to the annual chemical check of the well, also check the bacteriological quality of the water in the drinking water system.

Each laboratory has its own protocol for taking samples. Sometimes the livestock breeder may take the samples and send them to the laboratory. In most cases, a specialist comes to the farm to take the water samples.

Note
Have the water samples taken by a certified expert. This ensures that the samples are taken and treated properly.

# 4. Quality of livestock drinking water

The third step in the step-by-step plan is assessing the drinking water samples that were tested.

The table below: Drinking water standards for pigs and poultry, contains the normal and critical values used by the (Dutch) Animal Health Service when assessing the suitability of drinking water. Check the results of the water samples against the following table:

**Table: Drinking water standards for pigs and poultry****

| Parameter | Pigs* | | Poultry | |
|---|---|---|---|---|
| | good | abnormal | good | abnormal |
| pH | 5 - 8.5 | <4 and >9 | 5 - 8.5 | <4 and >9 |
| Ammonium (mg/l) | <1.0 | >2.0 | <1.0 | >2.0 |
| Nitrite (mg/l) | <0.10 | >1.00 | <0.10 | >1.00 |
| Nitrate (mg/l) | <100 | >200 | <100 | >200 |
| Chloride (mg/l) | <250 | >2000 | <200 | >2000 |
| Sodium (mg/l) | <400 | >800 | <100 | >200 (1) |
| Sulphate (mg/l) | <150 | >250 | <150 | >250 |
| Iron (mg/l) | <0,5 | >10,0 | <0,5 | >5,0 |
| Manganese (mg/l) | <1,0 | >2,0 | <0,5 | >1,0 |
| Hardness (°D) | <20 | >25 | <15 | >20 |
| Hydrogen sulphide | not detected | | not detected | |
| Coliform bacteria (cfu/ml) | <100 | >100 | <100 | >100 |
| Total bacterial count (cfu/ml) | <100.000 | >100.000 | <100.000 | >100.000 |

* Can also be used on horses and other monogastric animals
(1) for laying hens: > 400 mg/l sodium

Source: Animal Health Service (Netherlands)

** The 'good' columns contain the values for which the animal species in question experiences no negative effects. The 'abnormal' columns contain the limits at which the animal species in question experiences negative effects.

If parameters other than those included in table Drinking water standards for pigs and poultry, play a role with respect to the problems, the drinking water standards for human consumption are applied.

**Interpreting the water test**
In addition to a conclusion, some labs also give advice to the livestock breeder based on the results of the water testing, for example concerning improvements that could be made.

Possible contamination of the water with heavy metals and/or organic compounds (agricultural chemicals) is not tested.

If the water is characterized as 'less suitable ", it does not directly mean that the water is harmful, but that the quality of the well water compared to the quality of tap water is not optimal. The water can only be assessed in order to serve as drinking water for livestock. Assessing the water for human consumption is beyond the scope of investigation. The use of the tested water for human consumption is at your own risk.

Drinking water is rejected as 'fit for use in livestock':

1. If one or more parameters are above the level indicated in the column 'abnormal' in the table Drinking water standards for pigs and poultry.
2. If three or more parameters are between the standard norm and abnormal values of Table 1.

If all parameters have levels below the level 'good' the water is always seen fit for livestock consumption.

The parameters in drinking water do not influence each another, yet specific combinations can occur:

- If nitrite is present in the water, ammonium or nitrate will also be present depending on the amount of oxygen in the water.
- Manganese in water is always accompanied by iron.
- A high sulphate content is always accompanied by high levels of hardness.

## 5. Problems and solutions concerning parameters in drinking water

The fourth step in the step-by-step plan is addressing the drinking water's quality problem.

A detailed description of the various purification processes for drinking water is included in appendix 1 *Description of different purification processes for drinking water*.

### 5.1 Hardness values

Hardness up to 25°D is suitable for drinking water intended for pigs and broilers.
However, problems in the drinking water system can already manifest themselves at a hardness of 15°D. The lower limit for water hardness is set at 4°D. A general description of water hardness is given in appendix 4 *General parameters*. If the drinking water test shows that the water has an abnormally high level of hardness, this can cause calcium deposits in the drinking water system.

There are different levels of calcium deposits:

- The presence of calcium in drinking water is already a cause of deposits in the drinking water system.
- Heating water with high levels of hardness increases calcium deposits in the drinking water system.
- Calcium and magnesium in the water form complexes with various antimicrobials (such as tetracyclines). These complexes can clog the drinking nipples. More information on antimicrobials in drinking water can be found in Part III: Antimicrobials.

Appendix 5 *Problems with parameters* further explains the different levels of calcium deposits.

Problems with calcium deposits increase as the water hardness increases. The formation of calcium deposits might give the impression that the complete absence of substances such as calcium and magnesium would be desirable (soft water). Soft water, however, also erodes piping, hence the lower limit for hardness is set at 4°D. Iron for example tends to dissolve in soft water, which also has negative consequences for piping.

Note
The ideal level of hardness is between 13 and 17 °D. Within these limits, calcium deposits are minimal and corrosion problems are avoided.

**Consequences of calcium deposits**

Calcium deposits in the drinking water system decrease the flow of drinking water by reducing the diameter of the piping and the drinking water openings.

Possible consequences of poor drinking water flow are:

1. A decrease in the amount of drinking water available to the animal.The animal will not have access to the amount of drinking water it needs. Decreased water intake can lead to reduced feed intake, decreasing yield in the process. A protracted shortage of water can lead among others to dehydration in the animal.
2. Clogged drinking nipples.
   - Calcium in the drinking water comes in contact with oxygen from the air at the nipple. This can lead to calcium oxide (CaO) deposits on the outside of the nipple, causing the nipples to stick or become clogged.
   - A reduced flow of drinking water in the piping also reduces the flow of drinking water in the nipples. Since the opening in a drinking nipple is much smaller than the piping diameter, drinking nipples tend to become plugged by calcium deposits before the water piping itself.

3. The development of bacteria and other harmful substances in the piping. The reduced flow of water gives bacteria a greater chance to form into colonies. Calcium deposits roughen the surface of the piping, so bacteria and microorganisms can easily attach to the surface, which also promotes the formation of bacteria colonies. Bacteria colonies and microorganisms in the drinking water system restrict the piping diameter, resulting in a decreased flow of drinking water, and finally in blockage/silting up. The presence of bacteria and microorganisms in drinking water also increases the likelihood of disease in the animals, resulting in turn in decreased yield.

Hardness of 20°D and higher affects the taste of water. Animals, however, are able to adjust to this taste. Water intake decreases only at a hardness of 25°D. For poultry, a limit of 20°D is recommended due to complex formation of calcium and magnesium with antimicrobials.
When medication is administered via drinking water, it is recommended to soften the water in order to limit hardness to 20°D. This, however, is not mandatory.

Note
Have the water softening installation inspected by a specialist at least once per year.
Replace or repair the water softener when water hardness is 20°D or greater. If the farm has no water softening system, one will need to be installed. After installation, clean the drinking water system as described in Part II, section 4.4 *Cleaning procedure in the case of calcium and iron deposits*.

Softening reduces water hardness to 0°D. This has no negative consequences for animal health since the feed contains sufficient calcium.
However, a hardness of 0°D can affect the quality of the piping and the pH of the water. Soft water is corrosive. When hardness decreases, so does the pH, and a low pH corrodes the piping.

Note
To prevent corrosion in the piping due to soft water, it is recommended that the soft water be mixed with hard water: 2/3 soft water to 1/3 hard water.

The most common method for softening drinking water in the livestock sector is ion exchange.
A detailed description of softening water via ion exchange is given in appendix 2 *The purification process per parameter*.

A softening installation does not require much maintenance. Parts must be replaced occasionally, and the installation must be cleaned. A softening installation is usually replaced every ten years, assuming that the installation is properly used.

## 5.2 Iron levels in water

Drinking water with iron levels less than 0.5 mg/l is suitable for pigs and broilers. However, iron concentrations higher than 0.5 mg/l can cause problems in piping and drinking water systems. A general description of iron levels in water is given in appendix 4 *General parameters*.

If drinking water contains too much iron, several problems can result:

a) Iron concentrations in the drinking water higher than 2.5 mg/l can clog drinking nipples. The reaction that leads to deposits is further explained in appendix 5 Problems with parameters. The red-brown iron deposit in the drinking water system decreases the flow in the drinking water by decreasing the diameter of the water piping and clogging drinking nipples. Possible consequences of poor flow in the drinking water system are a decrease in the amount of water available to the animal, clogged drinking nipples and the development of bacteria, yeasts and moulds in the drinking water system.

b) Iron concentrations above 5 mg/l make the water unsuitable for administering medication via the drinking water. Various medicines or mediums for medication (tetracyclines for example) can react with iron. When this happens, complexes are formed that deposit in the water piping. This in turn can clog drinking nipples. Some medications retain their inherent effectiveness, but cannot be absorbed by the animal due to deposits in the piping. Other medications lose their effectiveness after exposure to deposits.

c) With iron concentrations greater than 10 mg/l, the taste of iron is strong and thus livestock drink less. Decreased water intake leads to reduced feed intake, and thus to decreased yield.

d) Iron concentrations greater than 30 mg/l can cause diarrhoea in livestock. Sick animals eat less and, in the case of protracted illness, also drink less. Both cases result in reduced yield.

e) Water containing iron promotes the growth of so-called 'iron bacteria' (also called 'crenotrix'). Iron bacteria very quickly develop into large bacteria colonies that attach to the water pipes and decrease the flow of drinking water. If iron bacteria colonies dislodge from the piping, blockages in the drinking water system can result. Decaying iron bacteria give off an unpleasant odour in the water. Iron bacteria absorb iron ($Fe2+$) and convert it to hydrated iron hydroxide (deposits).

Note
Have the deferrization installation checked by a specialist at least once per year. Replace or repair the deferrization installation when iron levels in the water are too high. If the farm has no deferrization installation, one will need to be installed. After installation, clean the drinking water system as described in Part II, section 4.4 *Cleaning procedure in the case of calcium and iron deposits*.

A description of the process of deferrization is given in appendix 2 *Purification processes* per parameter. A deferrization installation is the most common type of water treatment used in livestock breeding. A well-maintained deferrization installation has a life of approximately 10 years.

### 5.3 Manganese levels in water

Higher concentrations of manganese result in problems in the drinking water installation over time. To avoid these problems in the piping and/or drinking water system, the water should contain less than 0.05 mg/l of manganese.

Suitable manganese levels in drinking water would be less than:

- 1.0 mg/l for pigs
- 0.5 mg/l for broilers

A general description of manganese levels in water is given in appendix 4 General parameters. If the drinking water test shows that the water has abnormally high levels of manganese, this can point to a problem: corrosion of the water pipes and the drinking water system.

There are different levels of manganese deposits:

a) Water with manganese levels above 2.0 mg/l can corrode stainless steel and form deposits due to a reaction with oxygen in the water. Appendix 5 Problems with parameters further explains the reactions between manganese and stainless steel, and between manganese and oxygen.

b) High manganese levels in water can corrode piping, resulting in leaks in the drinking water installation. It remains unclear which materials are affected by manganese and in which way.
  - Leaks result in wet places in the stables. Especially poultry are very susceptible to the quality of stable litter. Poor quality stable litter results in increased disease and production losses in chickens.
  - Leaks and the resulting lost water can also decrease the amount of drinking water available to animals. Decreased water intake leads to reduced feed intake, and thus to decreased yield.

c) Damage to the piping from high manganese levels roughens the surface on the inside of the piping. Bacteria and microorganisms can easily attach and develop on a rough surface, causing blockages in the drinking water system.

d) Manganese causes a worsening in the taste and smell of water. Decreased taste and smell result in reduced water intake, leading in turn to reduced feed intake. And decreased feed intake results in decreased yield.

High manganese levels in the drinking water system can cause problems. If, however, the water pipes are adequately thick, damage to the piping by manganese can take up to ten years. Manganese can be removed from the water with a deferrization installation.

Note
Have the deferrization installation inspected by a specialist at least once per year. Replace or repair the deferrization installation when manganese levels in the water are too high. If the farm has no deferrization installation, one will need to be installed. Then clean the drinking water system as described in Part II section 4.1 *General cleaning and disinfection*.

A description of the process of removing manganese is given in appendix 2 *Purification processes per parameter*.

## 5.4 Levels of ammonium, nitrite and nitrate

Levels of ammonium, nitrite and nitrate in drinking water are suitable in the following concentrations:

- Ammonium levels less than 1.0 mg/l for pigs and poultry
- Nitrite levels less than 0.10 mg/l for pigs and poultry
- Nitrate levels less than 100 mg/l for pigs and poultry

A general description of ammonium, nitrite and nitrate levels in water is given in appendix 4 *General parameters*.

If the drinking water test shows that the water has abnormal levels of ammonium, nitrite and nitrate, the following problems can arise:

**a) Problems in the animal.**

- Ammonium can be toxic in the animal body.
  When converting ammonium via nitrate and nitrite into proteins in the animal body, several intermediate substances such as nitrosamines can be formed. The formation of intermediary products and the opportunity for nitrosamine formation should be avoided, hence the norm for nitrite is 0.10 mg per litre for pigs and poultry.

- In the animal body, nitrite binds to haemoglobin in the blood, preventing the haemoglobin from transporting oxygen. Nitrite concentrations of approximately 1,000 mg/l water can result in acute death in animals. In nitrite concentrations less than 1,000 mg/l, the following symptoms can appear:

  - Lowered blood pressure
  - Kidney damage

- Approximately 5% of nitrates absorbed by the body are converted into nitrites by bacteria. As indicated above, nitrites attach to haemoglobin, preventing the haemoglobin from transporting oxygen. During the winter months, surface water can contain relatively high concentrations of nitrates (0.5 to 0.8 mg/l) due to the incomplete conversion of nitrates to ammonium.

- High nitrate concentrations can lead to intoxication, especially in young animals. High concentrations of nitrates in drinking water can be caused by nitrogen from the ground that is absorbed by well water.

**b) Problems in the drinking water system.**

- The presence of high levels of ammonium compared to nitrate levels indicates bacterial contamination in the piping and drinking water system. Ammonium is a breakdown product of bacteria. Bacterial contamination can lead to:
  - The silting up or blockage of piping and drinking nipples, leading to a reduction in the amount of drinking water available to the animals. Decreased water intake leads to reduced feed intake, and thus to decreased yield.
  - An increased risk of pathogens and their poisonous substances in the drinking water, which could be a source of disease in animals. Increased ammonium levels often result in pH levels as high as 8.
- High ammonia and nitrite concentrations decrease the taste of drinking water. When the taste of drinking water is reduced, animals drink less water, leading to decreased feed intake, and thus to decreased yield.
- Nitrite reacts with iron II salts ($Fe^{2+}$) in the drinking water.
  - When nitrite and iron react in piping and drinking water systems, iron III salts ($Fe^{3+}$) deposits are created. Deposits in piping and drinking water systems result in a decreased flow of drinking water, reducing the amount drinking water available to the animals. As stated earlier, decreased water intake results in decreased feed intake, thereby reducing yield.
  - When nitrite and iron(II) react in the animal body, bound iron(III) is formed. Bound iron(III) attaches to the haemoglobin, reducing the amount of oxygen the heamoglobin is able to transport.

The nitrification process converts ammonium and nitrite into nitrate. The nitrification of ammonium and nitrite into nitrate takes place in a deferrization installation.

Note
Replace or repair the deferrization installation when the level of ammonium and/or nitrite in the water is too high. If the ammonium level in a well deviates strongly from the norm, such that it is difficult to purify the water, the livestock breeder is recommended to have a new well drilled. After solving the problem, clean the drinking water system as described in Part II section 4.1 *General cleaning and disinfection*.

A description of removing ammonium is given in appendix 2 *Purification process per parameter.*

### 5.5 Sodium and chloride levels

Sodium and chloride in drinking water are suitable in the following concentrations:

- Sodium less than 400 mg/l for pigs and less than 100 mg/l for poultry.
- Chloride less than 250 mg/l for pigs and less than 200 mg/l for poultry.

A general description of sodium and chloride in water is given in appendix 4 *General parameters.*

If the drinking water test shows that the water has abnormal levels of sodium chloride, the following problems can arise:

Consequences for the animal.

- Excess sodium can cause salt poisoning (sodium poisoning). Problems with animals can be expected if the sodium level is above the indicated limits. The animal will die quickly when the limit is exceeded. If the feed contains a relatively high amount of sodium, the level of sodium in the drinking water should be minimal. This is impossible with sodium levels above 400 mg/l (pigs) and 250 mg/l (poultry), and in these cases, the animal will die from sodium poisoning.
- Increased sodium and chloride levels reduce the taste of drinking water. If the taste of the drinking water is affected too much, animals will drink less water, thereby reducing the feed intake. As indicated above, decreased feed intake results in decreased yield.

Increased levels of chloride in the water have few health effects, but do indicate that the water in the system is contaminated with other substances that could be poisonous, such as sulphates and phosphates. Sodium, chloride and sulphate can be removed from the water using reverse osmosis.

Note
Have the reverse osmosis installation inspected by a specialist at least twice per year. Replace or repair the reverse osmosis installation when the level of sodium, chloride and/or sulphate in the water is too high. If no reverse osmosis installation is present on the farm, one should be installed.

A detailed description of reverse osmosis can be found in appendix 1 *Description of various purification processes for drinking water.*
Reverse osmosis for the treatment of water is not often used in livestock breeding.
The investment required is quite large.

### 5.6 Levels of hydrogen sulphide and sulphate

Hydrogen levels in drinking water are safe when the sulphate concentration is less than 150 mg/l for pigs as well as poultry. It is not possible to indicate hydrogen sulphide concentrations. It can only be recognised by its smell. A general description of hydrogen sulphide and sulphate levels in water is given in appendix 4 *General parameters*.

If the drinking water test shows that the water has abnormal levels of hydrogen sulphide and sulphate, the following problems can arise:

- The presence of hydrogen sulphide in drinking water indicates that the water is 'rotting'. The presence of hydrogen sulphide in drinking water is a sign of anaerobic decomposition. Further investigation is unnecessary, since the gas can be directly ascertained by smell. This gas is one of the most poisonous of substances. Hydrogen sulphide in drinking water causes:
  - Damage to the nervous system, brains, kidneys and heart.
  - Damage to the sense of smell. Because of this, the gas present can no longer be smelled after a time.
- A high sulphate concentration is not serious, but can cause soft dung in the animals (no diarrhoea). Soft dung is caused by hard water (higher than 25° D), when the water has high level of magnesium (greater than 40 percent). This creates the laxative 'magnesium sulphate'. The increased level of magnesium sulphate causes water retention in the intestine (causing soft dung).

If both substances (hydrogen sulphide and sulphate) are present, the assumption is that that intermediary compounds (such as sulphite and S-8) are also present. Sulphide is very poisonous. Concentrations less than 0.02 mg/l cannot be detected in drinking water. However, sulphide can be detected due to its odour. Removing sulphate is described in section 5.5 *Abnormal sodium and chloride levels*. Hydrogen sulphide is removed via a degassing and aeration step before the water passes through the sand filter in a deferrization installation.

Note
Have the deferrization installation inspected by a specialist at least once per year. Replace or repair the deferrization installation when the hydrogen sulphide level of the water is too high.

## 5.7 pH levels

Safe pH levels in drinking water are between 5 and 8.5 for pigs as well as poultry.
A general description of pH in water is given in appendix 4 *General parameters*.

If the drinking water test shows that the water has a pH less than 4 or greater than 9, the following problems can occur:

- A pH less than 4 or greater than 9 decreases the taste of water.
- Poorer tasting drinking water will cause the animals to drink less.
- Decreased water intake leads to reduced feed intake, and thus to decreased yield.

The pH of the water depends among others on the water's buffering capacity, which in turn is determined among others by the hardness of the water; the harder the water, the less the pH changes. Soft water has a hardness of 0° D. The buffering effect of the water disappears, which can lead to a sudden lowering of acidity that can corrode piping. A hardness of 4° D is needed to prevent damage to the drinking water system.

## 5.8 Bacterial count

The bacterial count measures the growth of bacteria in the drinking water system. The total bacterial count gives a picture of the general hygiene of the drinking water. Water is never fully germ free.

Acceptable bacterial counts are:

• 100,000 microorganisms per millilitre water (100,000 cfu/ml water) for both pigs and poultry.

*E. Coli* can cause disease, hence a separate test is done for the presence of *E. Coli* in water. The maximum acceptable level of *E. Coli* microorganisms is less than the total bacterial count, namely:

• Less than 100 cfu/ml drinking water for pigs as well as poultry.

A raised *E. Coli* bacterial count can indicate contamination of the water with dung and potential rampant growth of the *E. Coli* microorganisms in the water piping or supply tank/ float tank. The presence of *E. Coli* indicates recent contamination.

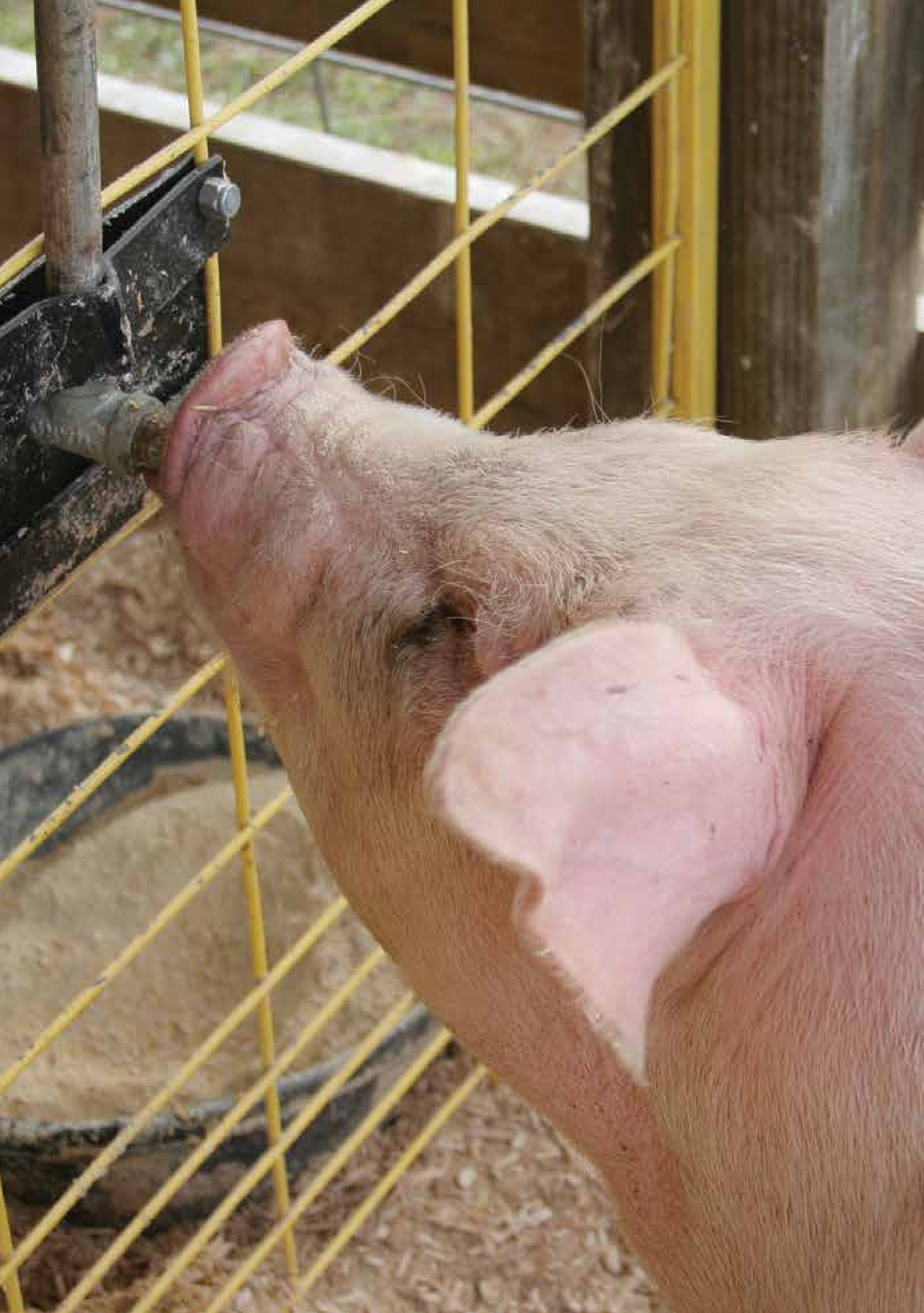
Both the total bacterial count and the *E. Coli* number are expressed in the number of 'colon forming units' per ml water = cfu/ml.

**Removing bacteria from well water**
Bacteria and microorganisms can be removed from well water via reverse osmosis. After solving the problem, clean the drinking water system as described in Part II section 4.5 *Cleaning in the case of a high bacterial count*.

A detailed description of reverse osmosis can be found in appendix 1 *Description of various purification processes for drinking water.*

If the water has a high bacterial count, the drinking water system should be checked at several points. More information on checking the drinking water system can be found in Part II: Chapter 3 *Testing the drinking water system*.

# PART II DRINKING WATER SYSTEMS



## 1. Introduction

It is important that the drinking water is able to flow through the piping and out of the drinking nipples or other taps without obstruction. Blockages in piping or nipples can drastically reduce the availability of water to the animals. If the availability of water is too low, the water intake can decrease. A lower water intake also means a lower feed intake, and hence a lower yield.

To ensure the proper availability of drinking water for animals and the correct administration of drinking water medication, in addition to good quality drinking water, a good drinking water system is very important.

Drinking water problems developing after the administration of antimicrobials usuall indicate poor water quality or a poor drinking water system.

When problems occur on a farm after the administration of medication via the drinking water, in addition to a test of the water quality, a thorough test of drinking water systems is important.

This part of the guide treats the ways in which a poor drinking water system can cause problems such as clogged piping and nipples.

It also defines what a good drinking water system is and how to prevent or remedy problems.

## 2. Drinking water systems in general

Drinking water enters the stable via piping from the source. Water supply can either be a well, or the commercial supplier. A control unit is usually placed centrally in the stable, in the central hall or at another central point. Here all necessary regulation equipment is installed. On this control unit, all handling can be done to switch from normal drinking water to medicated drinking water per animal compartment. The control unit or central point consists of the water supply piping, a water filter, a bypass, a pressure regulator and a water meter.

The water meter measures the amount of water the animals drink. A dosing device can be installed just behind the water meter. In case of an electronic dosing pump, the water meter is included in the pump. The actual drinking water system begins just behind the dosing device.
A schematic view of a control unit is given in the following diagram below.

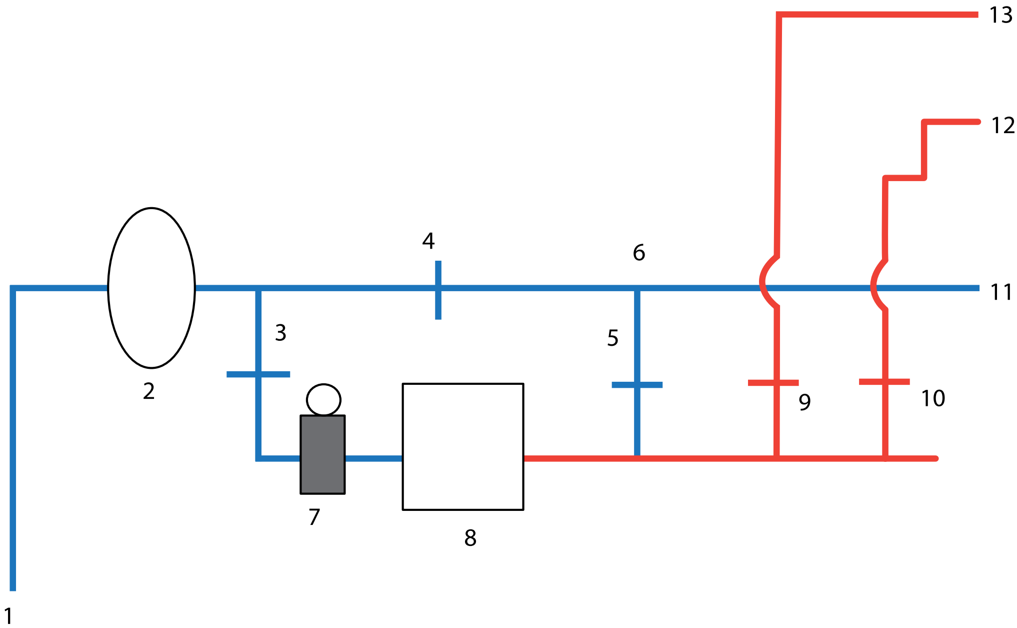


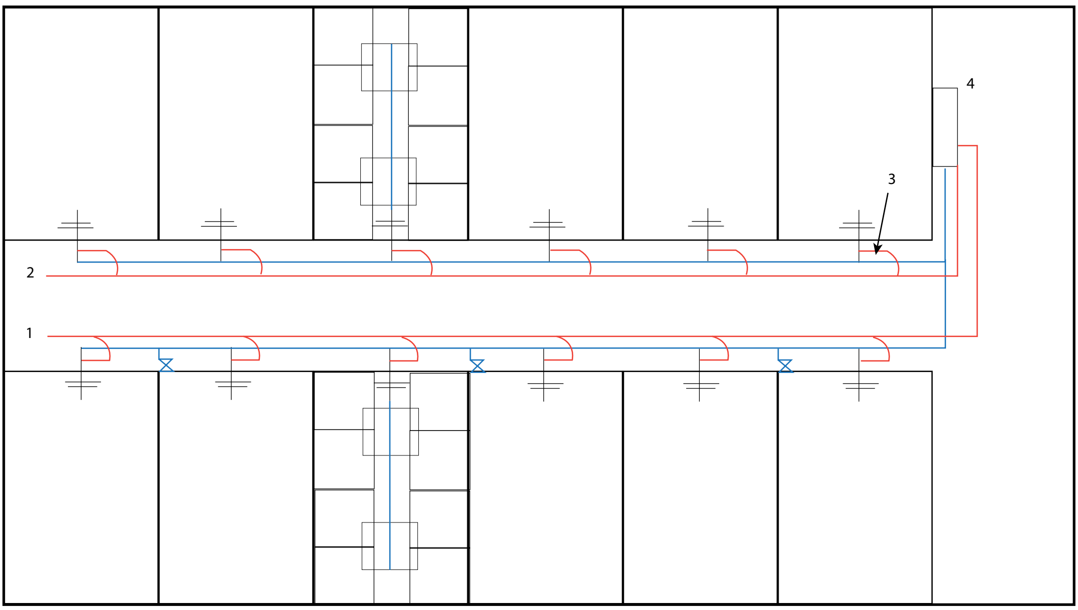

**Diagram control unit**
1. Water supply
2. Water filter
3. PVC ball valve blue
4. PVC ball valve blue
5. PVC ball valve blue
6. Bypass
7. Pressure regulator
8. Dosing device
9. PVC ball valve red
10. PVC ball valve red
11. Water transport piping to the animal compartments
12. Transport piping for medicated water (or other supplements)
13. Transport piping for medicated water (or other supplements)

In pig stables, the water piping is often split into piping for normal drinking water and piping for medicated drinking water. PVC ball valves are installed in the piping to separate normal drinking water from medicated drinking water. Installing separate piping for medicated drinking water makes it possible to administer medication per section. The pipes run parallel to each other until the start of the section. At the start of the section, the two pipes merge into a single pipe that enters the section. At the start of the section, a valve that can be closed or opened is located in the main piping and in the medicine piping. A decision can be taken per section concerning whether medicated or normal drinking water enters the section.

The diagram below *Drinking water systems in pig stables* provides a schematic view of a drinking water system in pig stables.

- blue lines = drinking water piping
- red lines = medicated water piping

**Diagram: Drinking water system in pig stables**

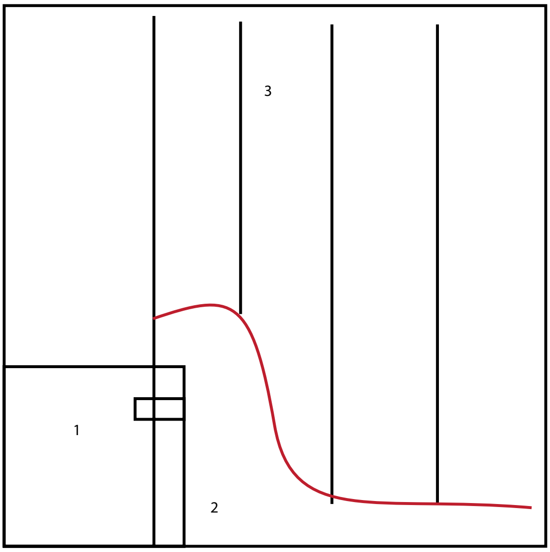



1. Ball valve for draining (rinsing valve)
2. Ball valve for draining (rinsing valve)
3. Set of valves per section (2 PVC ball valves: red and blue)
4. Central point

Separate piping is almost never used for medicated drinking water in broiler housing. Because broiler farms operate according to the all-in/all-out principle, the stables are not divided into different sections.

The diagram below *Drinking water systems in broiler housing* includes an example of a drinking water system in broiler housing.

**Diagram: Drinking water system in broiler housing**

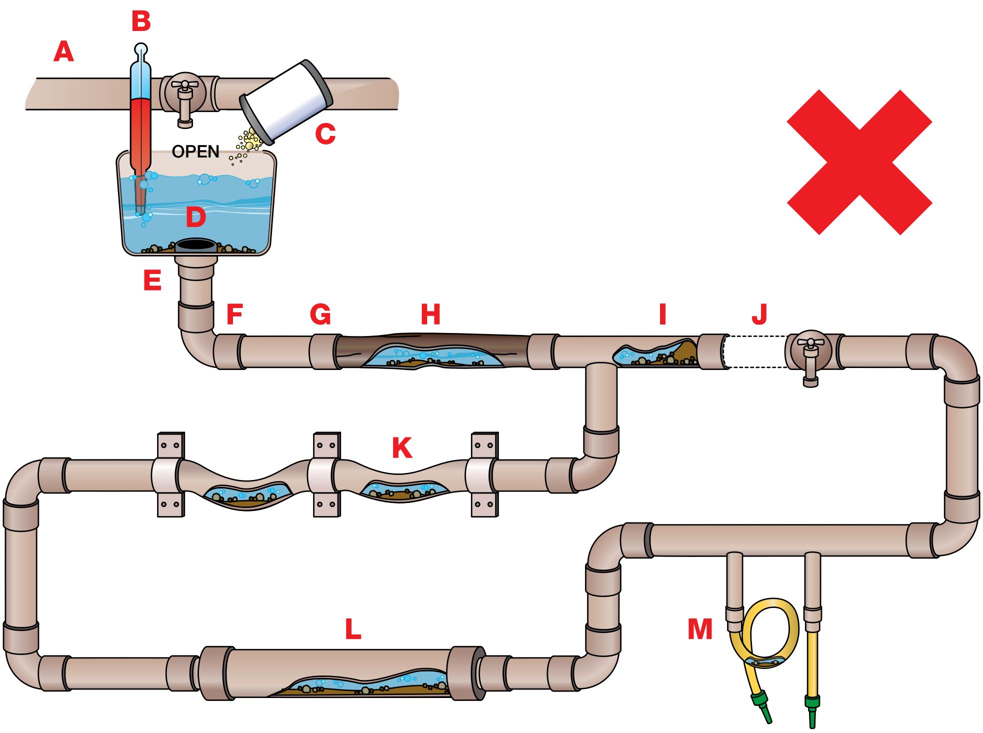



1. Central point
2. Polyethylene main piping
3. PVC transport piping

Drinking water systems can be delivered and set up by various companies. There is little difference in quality between materials used for drinking water systems by the various companies. Because many livestock breeders opt to install drinking water systems themselves, huge differences exist in how drinking water systems are set up.

## 3. Evaluating the drinking water system

Appendix 6 *Checklist for drinking water systems* contains a checklist for evaluation of drinking water systems. A farm in which problems arise after the use of a drinking water supplement needs to be checked. The diagram below indicates the critical points of a drinking water system. The concerned paragraphs are indicated in brackets.




A. No water treatment equipment installed
B. Temperature of the incoming water too high
C. Water Medication products containing lactose
D. Open float tanks inside animal compartments
E. Tank connection / installation mistakes
F. Excessive bends in the pipelines
G. Couplings do not fit
H. Rough inner surface of the pipeline material (eg. iron)
I. Dead end pipelines
J. Circular pipelines
K. Sagging pipelines
L. Varying diameter causing changes in water flow
M. Loops in plastic hoses with nipples

## 3.1 Water quality

Locating the cause of problems in providing water for pigs and broilers begins with an assessment of the water quality. For more information on water quality and water testing, reference is made to Part I *Drinking water quality*.

## 3.2 Drinking water supplements

When a farm is inspected after a problem arises related to drinking water and drinking water medication, an inventory must be made of all drinking water supplements that were added until the last time the system was cleaned.

It is important that the drinking water system is cleaned after each time a supplement is added. Not cleaning the system between drinking water supplements could lead to blockages. Remnants of drinking water supplements in the piping serve as a breeding ground for microorganisms. When many microorganisms are present in the piping, the piping tends to silt up. Often problems in drinking water systems, such as clogged piping and nipples, arise after the use of antimicrobials. Antibiotic products generally leave remnants behind in the water pipes that serve as a breeding ground for microorganisms (i.e. carrier substances such as lactose). Microorganisms grow more quickly in water pipes when more nutrients are present. Moreover, the addition of antimicrobials disrupts the equilibrium in the piping, thus allowing microorganisms such as moulds and yeasts to gain the upper hand, since their growth is no longer impeded. Hence, colonies of microorganisms can become so large that the water pipes become clogged.

For more information on how antimicrobials behave in drinking water, reference is made to Part III *Antimicrobials*.

Note
Make an inventory of all drinking water supplements used until the last time the drinking water system was cleaned. Also make an inventory of how the drinking water system was cleaned.
For more information on cleaning, see Chapter 4 *Cleaning and disinfecting drinking water systems.*

### 3.3 Float tanks

The analysis of the drinking water system begins with establishing whether float tanks or break tanks are present on the farm. The hygiene of the float tanks must be checked by examining whether they contain deposits. The hygiene of the water in the float tank can be verified by draining water into a white cup.

Float tanks are installed to regulate the pressure in water pipes. Generally, a water pressure between 0.5 and 1.0 bar provides a sufficient flow of water. In addition to the use of float tanks, water pressure can also be regulated with pressure regulators.

Moreover, many farms that are connected to the public water system are required to include a device in the drinking water system to prevent water from flowing back into the public water system.

A break tank is a float tank that not only reduces pressure in the piping but also forms a break between the public water system and the drinking water system. Often float tanks (and break tanks) are not properly closed, thus constituting an ‘open’ drinking water system. Open float tanks are quickly contaminated with dirt or, for example, dead flies. Dead mice or rats are also found regularly in float tanks.

Poor float tank hygiene results in a drinking water bacterial count (number of microorganisms expressed in colony forming units per millilitre (cfu/ml)) that is too high. Drinking water supplements used with a high bacterial count can cause piping to silt up quickly. Antibiotic products usually leave remnants behind in water pipes that can serve as a breeding ground for microorganisms. Microorganisms grow more quickly in water pipes when more nutrients are present. Moreover, the addition of antimicrobials disrupts the equilibrium in the piping, thus allowing microorganisms such as moulds and yeasts to gain the upper hand, since their growth is no longer impeded. Hence, colonies of microorganisms can become so large that the water pipes become clogged.

Since pressure regulators result in a closed drinking water system, pressure regulators are preferred over float tanks. To prevent high bacterial counts in the future, float tanks should be replaced by pressure regulators. Pressure regulators can only lower the water pressure. In pig stables, central piping with a higher pressure is usually installed, after which a branch is made to the different sections. A pressure regulator is installed per section for lower pressure. In poultry stables, it is possible to split the drinking water pipes and install a pressure regulator on each part.

A survey of the use of drinking water and drinking water medication in practice reveals that almost 50% of pig farmers use float tanks. 32% of pig farmers with a float tank never clean the float tank. The study also shows that 100% of the broiler farmers use pressure regulators. According to this study, float tanks are no longer used on broiler farms. Break tanks, however, are used for broilers.

Note

- Close float tanks and break tanks.
- Clean float tanks and break tanks regularly. For more information on cleaning float tanks, break tanks and drinking water pipes, reference is made to section 4.2 *Cleaning float tanks*.
- Possibly replace float tanks with pressure regulators.

### 3.4 Tank connections

The next step in analysing the drinking water system is checking the tank connections.

If the tank connection piping sticks out into the float tank, dirt can collect against the piping. The water located under the opening of the tank connection piping does not circulate and thus stagnates. Dirt can sink and pile up at this location.

Note
Remove the protruding part of the tank connection piping. This prevents problems due to a high bacterial count.

## 3.5 Bends and sags

The next step in analysing the drinking water system is determining the number of bends and sags in the piping.

Water pipes should be installed high and horizontally, with as few bends and sags as possible. The water flow in bends and sags is less than that in straight piping. The chance of sedimentation and accumulation of dirt (and thus of bacterial growth and blockages) is greater in bends and sags than in straight piping. High piping makes it possible to install connections to drinking nipples in a single downward line without bends.

If many bends and sags are found in the drinking water system, it can be advisable for the livestock breeder to have the drinking water system reinstalled by a specialist.

If the drinking water system is not reinstalled, but merely cleaned, after cleaning the bacterial count will increase quickly, again increasing the likelihood of blockages.

Note
Water pipes should be installed high and horizontally, with as few bends and sags as possible. If many bends and sags are found in the drinking water system, the livestock breeder is advised to have the drinking water system reinstalled by a specialist. Plastic piping should be attached to a steel pipe in order to prevent the piping from sagging.

## 3.6 Piping material

The next step in analysing the drinking water system is determining the material from which the piping is made.

Water pipes can be made of iron, galvanised iron, plastic or stainless steel. The advantages and disadvantages of these materials are explained in the following table Advantages and disadvantages of various types of material.

**Table: Advantages and disadvantages of various types of material**

| Type of material | Advantages | Disadvantages |
|---|---|---|
| (Galvanised) iron  | | Rust and corrosion by acids |
| Polyethylene  | Smooth surface on the inside | Lightly permeable for oxygen and ammonium<br>Not resistant to bites<br>Sagging |
| PVC  | Smooth surface on the inside<br>Durable | Lightly permeable for oxygen and ammonium<br>Not resistant to bites* |
| Stainless steel  | Smooth surface on the inside<br>Durable | High price |

*Standard PVC is not resistant to biting by pigs. There is a type of PVC that is stronger than standard PVC and is resistant to biting by pigs. This type of PVC, however, is more expensive than standard PVC.

### 3.6.1 Iron piping

Iron piping is corrosive. Ungalvanised iron water pipes rust on both the inside and outside. Galvanised iron water pipes only rust on the inside. While the piping still looks good on the outside, rust may have formed on the inside.

The iron in the piping dissolves in the drinking water. In the water, iron comes in contact with oxygen. Oxygen and iron react to each other and create an iron deposit in the piping.

With iron deposits (rust), a rough surface forms on the inside of the piping, to which dirt and remnants of drinking water supplements attach. Deposits of rust, dirt and remnants of drinking water supplements on the inside of the piping reduce the flow of water, allowing even more dirt to accumulate. Dirt and remnants of drinking water supplements serve as a breeding ground for microorganisms. The bacterial count in the piping increases. If there are many microorganisms present in the piping, the piping silts up more quickly after the addition of, for example, antimicrobials.

Nipples can also become clogged due to rust, and rust can give the water a strange taste so that pigs and broilers will no longer drink it.

After cleaning iron piping with a disinfectant, the bacterial count will increase quickly. Even if the iron deposits are removed with an acid, the bacterial count will increase quickly because new iron deposits will quickly appear. The use of acid in iron piping also increases the danger of leaks. In acid water (water with a low pH), iron dissolves much more quickly than in water with a pH of approximately seven, which can cause the piping to leak.

If a study of the drinking water system reveals the presence of iron piping, the livestock breeder is advised to replace the piping with piping made of plastic or stainless steel. It is important to examine the drinking water system thoroughly, since sometimes only small pieces of the piping system are made of iron.

### 3.6.2 Plastic piping

In addition to iron, piping can also be made of plastic. Examples of plastic piping are PVC and polyethylene piping.

The major advantage of plastic piping is that it is smooth, so that dirt and remnants cannot easily attach to it. However, the material is not resistant to nibbling and biting by pigs. Therefore, piping exposed to pigs should not be made of PVC or polyethylene. Moreover, the walls of plastic piping are often lightly permeable for oxygen and ammonium.

In the water piping, oxygen can react with, for example, iron or calcium, resulting in deposits in the piping. Ammonium is a breeding ground for certain microorganisms. Permeability for ammonium plays an important role especially in water pipes located under the floor. When for example the coating of floors wears or cracks, the concrete floor absorbs moisture from the stable that contains dissolved ammonium. If plastic piping has been installed under the floor, permeability for ammonium can cause blockage.

A major disadvantage of polyethylene piping is that the piping tends to sag. At places where the piping sags, there is a great likelihood of sediment, for example due to organic substances. The water flow is hindered by the sediment, and the sediment is an ideal breeding ground for microorganisms. In stables, bends in piping are often made of polyethylene, since polyethylene is easy to bend.

If inspection reveals that plastic piping on the farm is clogged, the livestock breeder should be advised to first clean the piping with a cleaning agent based on hydrogen peroxide to remedy the blockage.

Since polyethylene or PVC piping is lightly permeable for oxygen and ammonium, it is important that piping is cleaned regularly with an acid. An acid removes iron and calcium deposits in piping, keeping the surface of the piping smooth. In addition, an acid drinking water supplement disinfects when the pH of the water is lowered to under 4. Because an acid leaves behind organic contamination, after the addition of an acid, the drinking water system must be cleaned with a cleaning agent based on hydrogen peroxide. For more information on cleaning piping, reference is made to chapter 4 *Cleaning and disinfecting drinking water systems*.

Polyethylene piping that has sagged must be reattached. PVC piping that has sagged must be replaced. It is advisable to have the reattachment and replacement of piping done by a specialist.

### 3.6.3 Stainless steel piping

The best material for water pipes is stainless steel. Stainless steel piping has a smooth surface and is durable. And the walls of stainless steel piping are almost completely impermeable to oxygen and ammonium. In addition, stainless steel piping has good resistance to nibbling and biting by pigs.

A disadvantage of stainless steel is its high price. Moreover, stainless steel piping is slightly sensitive to corrosion. Stainless steel piping can become corroded especially when acid drinking water supplements are often used. Corrosion creates a rough surface, to which microorganisms can easily attach.

Note
Based on quality and price, the ideal drinking water system has piping made of a combination of stainless steel and PVC.

- The main piping and the supply piping in the section are made of PVC.
- In stables where pigs can contact the piping, stainless steel is used.
- The piping is installed horizontally and high, with as few bends as possible.
- Rigid, horizontal piping prevents sagging.
- Plastic piping should be attached to a steel pipe in order to prevent sagging.

### 3.7 Temperature

The next step in analysing the drinking water system is determining whether certain locations in the drinking water system have a higher temperature than other locations.

It often happens on farms that piping is located in front of or behind heating pipes, or that pipes are installed close to each other. The water piping is warmed in locations where it comes into contact with the heating pipe, creating a positive climate for microorganisms. When for example antimicrobials are added with carrier substances that can serve as a breeding ground for microorganisms, this location will quickly become clogged.

Note

- If heating pipes come into contact with drinking water pipes on a farm, the livestock breeder is advised to insulate the heating pipe.
- If a new piping system is installed, it is advisable to prevent heating pipes from coming into contact with drinking water pipes.

## 3.8 Dead-end piping

The next step in analysing the drinking water system is determining whether there is any dead-end piping in the system.

Dead-end piping should be avoided as much as possible. There is no flow in deadend piping, and the water assumes the temperature of the surroundings. There is a great likelihood of bacteria growth in deadend piping.

The piping can terminate at the nipple in pig housing. If the piping ends with a plug or a drain tap, it is important that this is used regularly when cleaning the drinking water piping.

In broiler housing, the piping usually terminates with a plug or drain tap. Broiler farms have empty coops approximately every seven weeks. This is a good time to thoroughly clean piping with a cleaning agent based on hydrogen peroxide.

In some farms, the piping of the sections reconnects to the main piping. Circular piping has no advantages over piping that ends at a nipple. However, circular piping is more expensive than a system in which the piping terminates at a nipple.

Some farms utilise a pump for circulating water in the main piping. This system has advantages, especially in straw stables, since the piping cannot freeze as easily. A circulation pump, however, offers no advantages for the most commonly used stables. In a properly installed drinking water system, the water flow is sufficient to ensure that fresh water is always available. A circulation pump is more expensive than a normal system since more piping material and more energy is used.

Note
Dead-end piping, without drain tap or plug, should be removed or a plug or drain tap installed. However, it is important in this case that stop and drain taps are regularly used to clean the piping. For more information on cleaning drinking water systems, reference is made to chapter 4 *Cleaning and disinfecting drinking water systems*

## 3.9 Couplings and piping diameter

The next step in analysing drinking water systems is checking the connections and the piping diameter.

At piping connections, ensure that the couplings are properly installed. Also be sure not to use too much glue. Excess glue on the inside of piping results in roughness where dirt can attach, which leads to blockages.

Correct water flow is important to ensure proper freshness and to prevent the sedimentation of particles. The water flow rate is partly determined by the piping diameter. The flow rate decreases as the diameter of the piping increases.

Hence, it is not true that thicker piping is better. It is very important that piping always has the same diameter. If a part of the piping in a drinking water system is replaced for example by piping with a larger diameter, the flow rate of the water will suddenly decrease, allowing solid particles to sink. Dirt will accumulate at the place where the flow rate decreases. Dirt can serve as a breeding ground for bacteria, causing the bacteria count in the piping to increase.

Note
Water pipes in sections should have a diameter between 15 mm and 25 mm (1 inch). The main piping in the central aisle should have a diameter of 25 to 40 mm.

### 3.10 Watering stations

The next step in analysing the drinking water system is checking the watering stations. When inspecting the watering stations, the level of water spillage, water flow rate, water intake, hygiene and the material used are very important.

- In the case of spillage and increased consumption due to higher nipple flow, manure volume will increase and its quality decrease. There is little spillage in both slurry troughs and drinking troughs. Section 3.10.1 *Watering stations piglets and pigs* indicates the criteria that must be met for watering stations for various types of pigs. Section 3.10.2 *Watering stations broilers* indicates the watering station criteria for broilers.

- Possible causes of inadequate water flow at the nipples include the following:
  - Partial silting up of the nipples or piping
  - Inadequate supply pipe diameter
  - Too many nipples connected to the supply pipe
  - A float tank that is too small

- Water intake can be monitored via the water meter in the control unit. Water intake that is too low can indicate poor water quality. In the case of abnormalities, various water parameters can have a negative effect on the taste of water.

- When inspecting hygiene, attention should be paid to the location of the drinking troughs. The drinking troughs should be installed such that the animals are not able to excrete in them. Drinking troughs that do not continuously contain water are the most hygienic. For good hygiene, drinking nipples are preferred over drinking troughs. To limit the growth of bacteria in drinking troughs or drinking nipples, it is important to inspect drinking troughs daily for contamination, and clean when needed. Drinking nipples should be checked for contamination after each round and cleaned when needed.

- Drinking nipples and drinking troughs should be made of stainless steel. Drinking nipples or parts of drinking nipples are often made of iron. Iron can corrode, and rust can plug the nipples. In addition, a rough surface can lead to bacterial growth.

### 3.10.1 Watering stations piglets and pigs

The various watering stations for pigs have differences in quality. Watering stations, however,¸must fulfil the criteria described below. In general, nipples and drinking troughs must be made entirely of stainless steel.

**Watering stations for piglets in the farrowing stable**

- In the farrowing stable, piglets 10-14 days old receive unlimited drinking water via a bite nipple or drinking trough.
- Water flow for piglets in the farrowing stable should be 300 millilitres per minute.
- The drinking nipple or drinking trough should be located approximately 20 centimetres from the litter and at a height of approximately 20 centimetres.
- It is important to drain off water at the watering stations before piglets begin to drink. The water may have been stagnant for a time before the piglets begin to drink. Bacterial growth occurs in stagnant water, causing the bacterial count in the drinking water system to increase.

**Watering stations for weaned piglets**

- Weaned piglets should have access to unlimited drinking water.
- To limit spillage as much as possible, the water can be provided via drinking troughs. The exact number of piglets per drinking trough depends on the production system. For production systems in which large herds of weaned piglets are given slurry feed, one drinking trough per 15-20 piglets is adequate. For production systems in which weaned piglets are fed dry feed, one drinking trough per 10-11 piglets is adequate.
- Water flow for weaned piglets should be 500 millilitres per minute.
- The drinking trough should be located a least 50 centimetres from the corner. The underside of the drinking trough should be installed 10 centimetres above the floor.
- It is important that animals are not able to excrete in the drinking troughs. Consequently, the top of the drinking trough should be larger than the underside.

**Watering stations pigs**

- Pigs should have access to unlimited drinking water via drinking troughs or drinking nipples.
- The water flow rate of drinking nipples or drinking troughs should be 500 ml per minute.
- One drinking station is sufficient for 12 pigs. The underside of the drinking trough should be located approximately 15 centimetres above the floor. It is important that pigs always have access to drinking water.
- If pigs are given slurry feed, separate water provisions must be used.
- It is important that animals are not able to excrete in the drinking troughs. Consequently, the top of the drinking trough should be larger than the underside.

Note

- Drinking nipples and drinking troughs should be made of stainless steel.
- Drinking troughs that do not continuously contain water are the most hygienic.
- For good hygiene, drinking nipples are preferred over drinking troughs.
- To limit the growth of bacteria in drinking troughs or drinking nipples, it is important to inspect drinking troughs daily for contamination and clean when needed.
- Ensure that the top of the drinking troughs are larger than the underside.
- In the farrowing stable, drain off water before allowing piglets to drink.

### 3.10.2 Watering stations broilers

There are three systems for providing water to broilers: drinking nipples, drinking cups and round waterers. For hygienic reasons, drinking nipples are preferred over drinking cups and round waterers. The advantages and disadvantages of the various systems are described below.

**Drinking nipples**

The diverse brands and types of drinking nipples are constructed of stainless steel or a combination of stainless steel and plastic. The drinking nipples are attached to the underside of the water supply piping. To prevent water spillage, it is important to install nipples that close properly and to install spill or drip trays under the nipples. The supply piping to which the nipples are mounted is usually made of plastic. To prevent the plastic pipes from sagging, these should be attached to a steel pipe.

A major advantage of drinking nipple systems is the fact that it a closed water system, which means that the animals always have access to fresh water. Another advantage is that the system does not need to be cleaned daily. A drinking nipple system results in less spillage than a system with round waterers, and there is plenty of free room for the chickens to range. The water flow rate should be 50 millilitres per minute.

**Drinking cups**

Drinking cups can be attached on or under the water supply piping. There are two types of drinking cups. With the first type, the water supply is kept open by a metal spring while the cup fills. The weight of the water compresses the spring, causing the opening to close when the cup is full. With the second type, the chicken pecks a pen that causes the water to flow into the cup. When not in use, the pen shuts off the water supply.

To teach young animals to drink from the cups, plastic balls are placed in the cups or attached to the pen in the cup, thereby creating a float system and allowing a small amount of water to flow into the cup. When the water is visible, it is quickly located by the chickens.

A major advantage of drinking cups is that the water is easily accessible to the chickens. Hence, a system with drinking cups is advantageous especially in very warm periods. A system with drinking cups also makes it easy to check for blockages. A disadvantage of a system with drinking cups is that it is less hygienic than a drinking nipple system. Drinking cups should be cleaned daily, especially in the first weeks. After the chickens are a few weeks old, the drinking cups are pecked clean. Water in systems with drinking cups has a higher bacterial count than that in drinking nipple systems. Finally, another disadvantage is the decreased range space due to the drinking cups.

### Round waterers

Round waterers are made of high quality, impact resistant plastic. Water is supplied by means of a spring in the supply valve. The water level can be adjusted by changing the spring pressure.

A first advantage of a round waterer is that the chickens can easily learn to drink. Another advantage is that it is easy to adjust the water level.

The disadvantage of round waterers is that they are an open water system. Hence, the water is not always fresh. The round waterer is less hygienic than a drinking nipple. During the first weeks, round waterers should be cleaned daily, which makes it a labour intensive system. Another disadvantage of the round waterer is that the large water surface increases the relative humidity in the stable. And round waterers are more prone to spillage than nipple systems.

Note

- For hygienic reasons, drinking nipples are preferred over drinking cups and round waterers.
- To minimise spillage, a spill or drip tray is recommended. The hygiene of spill or drip trays should be checked daily.

## 3.11 Equipment for administering medication via drinking water

When analysing the drinking water system, the way in which medication is added to the drinking water must also be determined.

Medication can be administered via a medicine tank, via the float tank or using electric or mechanical dosing equipment. When administering using a medicine tank, the tank must be large enough to contain at least half of the water that is used in a 24 hour period. The medication must dissolve well, and the medicine tank should be easy to clean. The addition of medication to drinking water via a float tank is not advised for hygienic reasons.

Dosing equipment has the advantage that medication can be administered in pig farms per section. In both pig stables and broiler housing, this equipment has the advantage that a drinking water system can remain closed. When using dosing equipment, the use of a water meter is advised. The water meter measures the amount of water used by the animals. Using dosing equipment in combination with a water meter allows medication to be administered very accurately. Two types are available: mechanical and electric dosing equipment.

**Mechanical dosing equipment**

Mechanical dosing equipment is connected to the drinking water system after the control unit. The water flow activates a piston or membrane that draws the medication solution into the drinking water. A disadvantage of mechanical dosing equipment is that the units do not function at low water flow rates. In the case of young chickens and recently weaned piglets, water flow is often too low for the mechanical dosing equipment to operate properly. Moreover, mechanical dosing equipment is less accurate and it does not last as long as electric dosing equipment. However, the purchase price of mechanical dosing equipment is less than that of the electric version.

**Electric dosing equipment**

Electric dosing equipment uses a water meter. The water meter measures the amount of water flowing through the piping. A signal is emitted by the dosing equipment for each 250 cc of water flowing through the meter. The dosing equipment then injects medication into the drinking water. The signal level depends on the amount of water being used by the animals. This allows accurate dosing, even at low water flow rates.

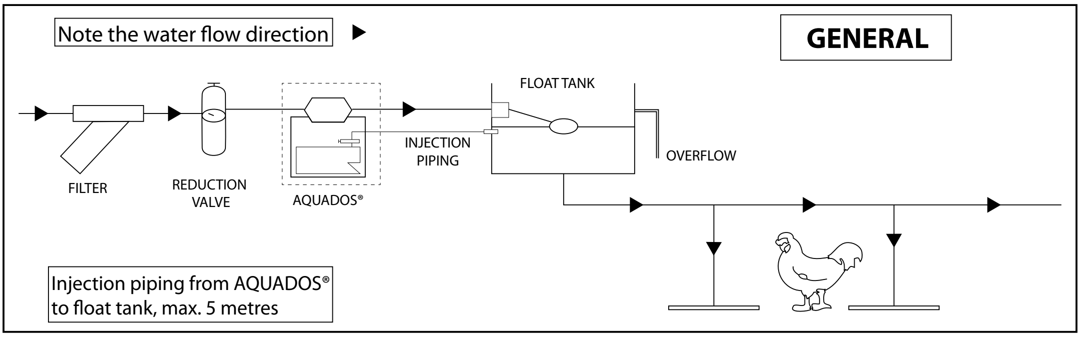
The electric dosing equipment is installed separately from the piping. Medication is injected into the drinking water via a hose. Often a digital counter measures how much water is used by the animals. A day counter is installed to check whether sufficient medication is administered. The data from the measuring instruments also allows early detection of potential problems with the pigs. Water intake levels often indicate sickness in pigs at an early stage. After use, the dosing equipment should be cleaned by allowing lukewarm water to circulate through it.

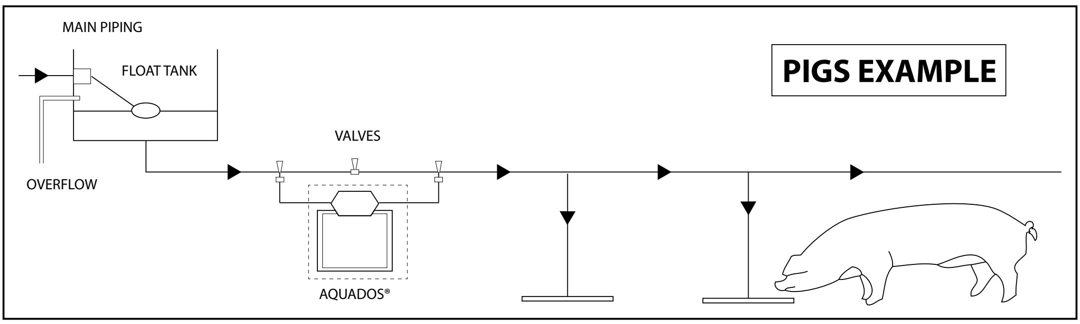
Electric dosing equipment is preferred over the mechanical type due to its greater accuracy. Accuracy is very important, especially when administering medication to young animals.

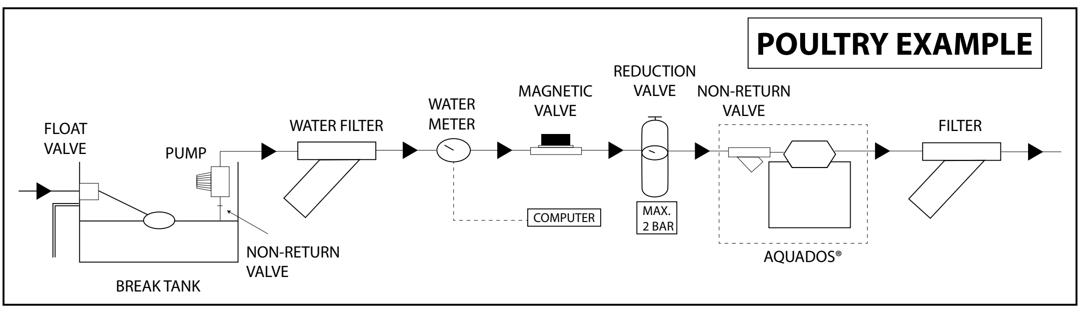
In addition to medication, cleaning agents and for example vitamin mixes can be added to the drinking water via dosing equipment.

The diagram below shows how metering pumps can be installed in three different stables.

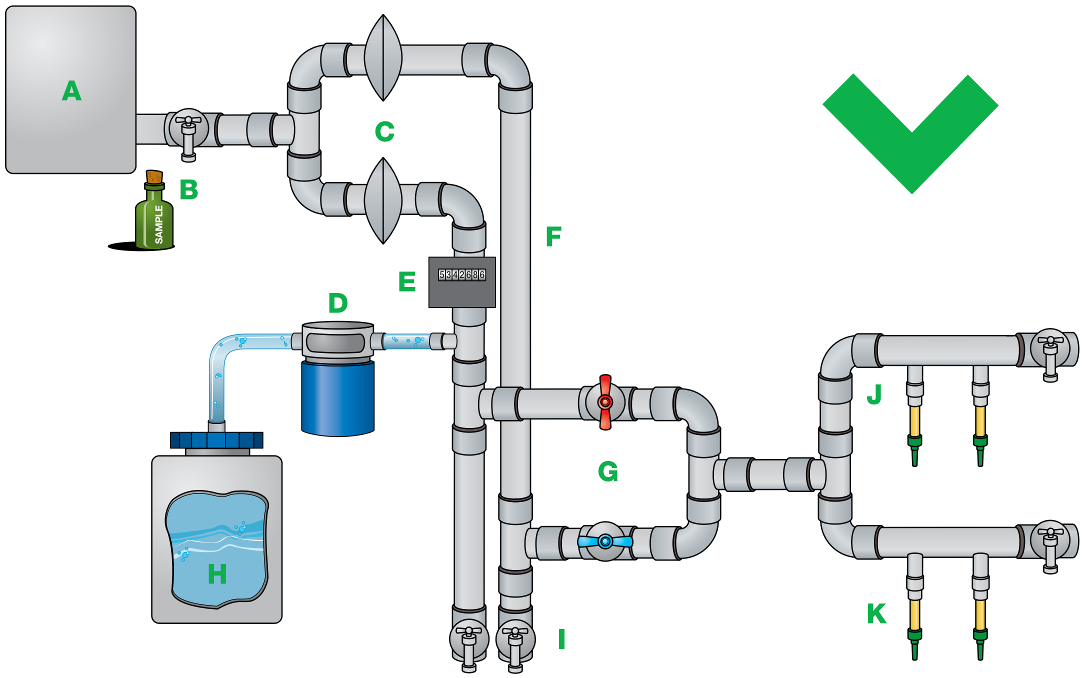
**Diagram: Aquados metering pumps**



### 3.12 Example of a good drinking water system




A. Water treatment installation (descaling or deferrisation)
B. A sample of the incoming bore hole water is taken regularly
C. Pressure regulators are present
D. A properly functioning metering pump
E. A flow controller records the water intake of the animals
F. It is a double system: one pipe is used only for clean water, the other only for medicated water
G. A choice can be made for clean or medicated water per section. Colored handles indicate which pipeline contains medicated water and which contains clean water
H. The medicine tank is closed with a lid and contains sufficient high concentration solution to provide medicated drinking water for up to 24 hours
I. Flushing tap
J. Each section has 1 or 2 single pipes with minimal bends and a flushing tap at the end
K. Drinking nipples hang directly under the piping with vertical hoses/pipes

# 4. Cleaning and disinfecting drinking water systems

## 4.1 General cleaning and disinfection

It is very important to clean and disinfect drinking water systems regularly, preferably every time the stable is empty when the animals are transported out. Cleaning should be done immediately after a round of administering medication via drinking water. Drinking water systems can also be cleaned before the use of medication, in order to be certain that the piping is clean when medication is added to the water. It is important that drinking water pipes are cleaned regularly to prevent potential problems such as clogged piping and drinking nipples.

A number of specialist products are available on the market to facilitate the proper cleaning and disinfection of piping. A survey of the use of drinking water and drinking water medication in practice reveals that livestock breeders clean piping using chlorine, organic acids, peracetic acid and/or cleaning agents based on hydrogen peroxide.

**Hydrogen peroxide**

The survey shows that 34.3% of pig farmers and 74.5% of broiler farmers clean piping using a cleaning agent based on hydrogen peroxide. Cleaning agents such as Hydrocare, Aquaclean, CID clean, CID 2000 and Pipeclean are based on hydrogen peroxide (H2O2). In addition to hydrogen peroxide, Hydrocare and Aqua-clean contain salt of silver as active ingredient, which increases the disinfecting action. The disinfecting action of CID 2000 is increased by the addition of peracetic acid. Cleaning and disinfecting agents based on hydrogen peroxide have an effervescent action that cleans piping mechanically. Because the cleaning agents can damage metal piping, protective agents are added that prevent corrosion in the piping. It is not clear which protective agents are used. Cleaning agents based on hydrogen peroxide clean organic contamination and manganese deposits in the piping. At concentrations of 2% and higher, these cleaning agents also have a disinfecting action that decreases the bacterial count in piping. For stables currently in use, cleaning can only be done with a hydrogen peroxide concentration of 0.0025%. Cleaning agents based on hydrogen peroxide do not remove iron and calcium deposits.

## Chlorine

The survey on the use of drinking water and drinking water medication in practice reveals that 5.7% of pig farmers and 56.4% of broiler farmers clean piping with domestic chlorine (sodium hypochlorite). The concentrations are expressed in terms of sodium hypochlorite levels. Livestock farms usually use 15% sodium hypochlorite concentrations. For cleaning drinking water systems, 50 ml of 15% sodium hypochlorite is added per 1000 litre water. Sodium hypochlorite disinfects, but does not remove deposits in piping. Due to the incomplete removal of deposits, after cleaning with chlorine, the bacterial count in the piping will again quickly increase. However, after cleaning with a cleaning agent based on hydrogen peroxide, sodium hypochlorite can be used to keep the bacterial count low. DM CID is based on chlorine and better suited to cleaning mildly dirty piping. DM CID can be used after thorough cleaning with one of the other agents.

## Organic acids

The survey shows that 27.7% of pig farmers and 31% of broiler farmers clean piping with organic acids. Acetic acid, citric acid, formic acid, propionic acid and lactic acid are examples of organic acids. Drinking water systems should be cleaned if the water test indicates that the hardness and/or iron content of water from a properly functioning purification plant is too high. Calcium and iron deposits are removed with organic acids. The Dutch Animal Health Service advises removing calcium and iron deposits with citric acid. Acetic acid and formic acid can also be used to remove calcium and iron deposits. Iron and calcium deposits can also be removed with Selko pH, which is a mixture of organic acids. When using simple acids such as citric acid, there is a risk that specific yeasts and mould that are not affected by the acid can obtain the upper hand. These yeasts and moulds are able to grow unhindered, which can also result in blockages. The uncontrolled growth of simple moulds and yeasts is less likely when a mixture of organic acids is used. The pH of the water must be reduced sufficiently in order to remove all iron and calcium deposits. However, the pH of the water may not be lower than 4 if animals are present. When the pH is less than 4, the water is less tasty, which reduces water intake. A lower water intake also means a lower feed intake, and hence a lower yield. Because acids leave organic remnants in the piping, it is important to clean the piping with an agent based on hydrogen peroxide, after cleaning with an acid. Cleaning agents based on hydrogen peroxide remove organic contamination in the piping.

## Peracetic acid

The survey shows that 1% of pig farmers and 20% of broiler farmers clean drinking water pipes with peracetic acid. Cleaning with peracetic acid is effective. Peracetic acid removes organic deposits and, if the pH is reduced to 4 or lower, iron and calcium deposits are also removed. Peracetic acid disinfects well, thus lowering the bacterial count in the piping. The use of peracetic acid is not recommended due to health risks for the livestock breeder and for the animals. Peracetic acid can produce chlorine compounds, which are suspected of being carcinogenic. Adding peracetic acid to water that contains organic substances can produce organic chlorine compounds (AOX). A German study shows that peracetic acid forms large amounts of AOX in both acid and alkaline environments. In the same situations, hydrogen peroxide appeared not to produce significant AOX. Hence, it is plausible that AOX can be formed, especially when using products containing peracetic acid such as CID 2000. Users of these products must take proper account of this. A healthier alternative for removing organic deposits is Aqua-clean. Here, the efficacy of the hydrogen peroxide is increased by adding salt of silver instead of peracetic acid. The increased efficacy of hydrogen peroxide due to this addition was demonstrated in an earlier study by the Animal Health Service. Hydrocare also consists of a combination of hydrogen peroxide and salt of silver.

## General notes

There are many different causes for clogged piping and nipples, hence unambiguous recommendations cannot be made concerning the cleaning of piping. The following paragraphs describe a cleaning procedure per cause. In general, it can be said that drinking water systems with iron and calcium deposits can best be cleaned with organic acids. For removing manganese deposits and organic deposits of drinking water supplements, it is best to use a cleaning agent based on H2O2. Of the cleaning agents based on H2O2, Aquaclean and Hydrocare appear to give the best results due to the addition of salt of silver. The use of peracetic acid is not recommended due to the health risks entailed. A cleaning agent based on chlorine can be effectively used after thorough cleaning with one of the other cleaning agents.

**Table: Cleaning agents**

| Cleaning agent | Brands | Use | Effects | Disadvantages |
|---|---|---|---|---|
| Organic acids | • Selko-pH<br>• Various simple organic acids such as citric acid | Iron and calcium deposits | Lowers the pH | Leaves behind organic remnants |
| Hydrogen peroxide | • Hydrocare<br>• Aqua-clean<br>• Pipeclean<br>• Cid-clean | After each addition of a drinking water supplement and in the case of manganese and organic deposits | Effervescent effect Disinfecting activity at concentrations > 2% | Does not remove iron and calcium deposits |
| Peracetic acid | • CID-2000<br>• Oxy-clean | Use not recommended | | Health risks |
| Chlorine | Various brands | After thorough cleaning with one of the other cleaning agents | Disinfects | Does not remove deposits |

## 4.2 Float tanks

If a check of the float tank shows that deposits are present, it needs to be cleaned.

- The water in the float tank needs to be drained; it is no longer suitable as drinking water for pigs.
- Livestock breeders must take into account the fact that water with a 1-3% Hydrocare or Aqua-clean solution is not suitable as animal drinking water. These concentrations do not entail any health risks, but drinking water consumption will decrease due to diminished taste. In addition, the loosened dirt causes blockages in the drinking water system.
- If the float tank can be detached from the drinking water system, the float tank should be cleaned manually with a brush and chlorine.
- If the float tank cannot be detached from the drinking water system, it can be cleaned with a 1-3% Hydrocare or Aqua-clean solution. The effervescent effect of H2O2 in combination with salt of silver removes deposits in float tanks.

## 4.3 Clogged piping

Clogged piping is best cleaned with a cleaning agent based on hydrogen peroxide. In the absence of animals or if the animals can be prevented from drinking the water, a cleaning agent based on hydrogen peroxide in concentrations of 1-3% can be added to the drinking water system. At these concentrations, the agent needs approximately one night to work.

In broiler housing, chickens can be prevented from drinking water with a cleaning agent by raising the drinking water pipes. After one night, the cleaning agent can be rinsed from the piping and collected in a bucket. (At a concentration of 6%, the cleaning agent can be rinsed from the piping after three to four hours.)

In pig stables, it is not possible to prevent pigs from drinking water with a cleaning agent added. Hence, in this case, it is very important to slowly build up the concentration of the cleaning agent. If a high concentration of cleaning agent is added immediately, the animals will no longer want to drink the water. Gradually building up the concentration causes the dirt to gradually loosen, but does not limit the water intake of the pigs. The following table describes a procedure for cleaning with animals present.

**Table: Cleaning procedure with animals present**

| Time | Dosage |
|---|---|
| 2 days | 50 ml Hydrocare or Aqua-clean/ 1000 l water |
| 2 days | 100 ml Hydrocare or Aqua-clean/ 1000 l water |
| 2 days | 150 ml Hydrocare or Aqua-clean/ 1000 l water |
| 2 days | 200 ml Hydrocare or Aqua-clean/ 1000 l water |
| Until the piping is clean | 250 ml Hydrocare or Aqua-clean/ 1000 l water |

Always act according to package and label instructions of the cleaning agent.

## 4.4 Calcium and iron deposits

When water testing indicates that the water in the well has a high level of hardness and/or a high iron content, the drinking water system should be cleaned with organic acids. When using simple acids such as citric acid, there is a risk that specific yeasts and mould that are not affected by the acid can obtain the upper hand. These yeasts and moulds are able to grow unhindered, which can also result in blockages. The uncontrolled growth of simple moulds and yeasts is less likely when a mixture of organic acids is used. The following table describes a procedure for cleaning the drinking water system with Selko-pH.

**Table: Cleaning procedure in the case of calcium and iron deposits**

| Time | Dosage |
|---|---|
| For 24 hours | 0.5-1.5 l Selko pH/ 1000 l water |

## 4.5 High bacterial count

When water testing indicates that the bacterial count is too high, piping and possible float tanks should be cleaned and disinfected. When animals are present, the drinking water system should be cleaned according to table 3 Cleaning procedure with animals present. In the absence of animals or if the animals can be prevented from drinking the water, the drinking water system can be cleaned with a 1-3% Hydrocare or Aqua-clean solution. A 1-3% solution requires one night to work.

## 4.6 Cleaning after adding drinking water supplements

If drinking water systems have already been thoroughly cleaned once, 100 ml Aqua-clean or Hydrocare per 1000 litre drinking water should be added for at least one day after the addition of each drinking water supplement such as medication, vitamins and organic acids. The cleaning agent removes remnants of drinking water supplements and ensures a clean drinking water system.

## 4.7 Points to keep in mind when cleaning

### Cleaning empty stables

1. Determine the construction of the drinking water system using table The construction of the drinking water system.

**Table: The construction of the drinking water system**

| | |
|---|---|
| Drinking water piping diameter | a. 25 mm = 2.5 cm |
| Stable length | b. 80 metres |
| Number of drinking water lines | c. 5 |
| Required Aqua-clean concentration | d. 2% |
| Content of piping network per metre | Surface area: $\pi * (½ a)^2 = 4.91 cm^2$<br>Content: surface * 100 cm / 1000 $cm^3$ = ½ ltr./metre |
| Drinking water system length | b * c = 80 * 5 = 400 metres |
| Desired Aqua-clean solution | 2% |
| Total needed | (200: 100) * 2 = 4 ltr. Aqua-clean or Hydrocare |

Please note: In this example, consideration is also taken of the 25% extra volume needed for filling nipples, cups and possible supply and return piping.

2. Ensure that the system can be bled
Aqua-clean and Hydrocare react immediately when exposed to organic contamination. In the process, hydrogen peroxide ($H_2O_2$) dissolves into water ($H_2O$) and oxygen ($O_2$). The oxygen gas formed must always be able to escape. The installation of a valve at the highest point in the drinking water system allows the system to be bled at any time. If the piping is very long, multiple bleeding valves are recommended.

3. Note the effervescent reaction
When filling the drinking water system, be sure to take into account the remaining water still in the piping. After adding Aqua-clean or Hydrocare to the water, the remaining water should be drained until the water on the ground begins to effervesce.

4. Raise each nipple and cup
Each nipple and cup has a nipple or cup cavity. This space will fill with the cleaning agent when the nipples are used. If the stable is empty, the nipple or cup cavity must be filled manually. In pig stables, drinking water systems are often installed in such a way that a branch from the main piping enters the section. This branch in the pipeline must be filled manually by moving the nipple.

5. Remove Aqua-clean or Hydrocare from the drinking water system
After Aqua-clean or Hydrocare has remained in the drinking water system for a night, it must be removed from the system. The system should be rinsed with clean water, and each valve and drain tap must be removed or opened. All nipples or drinking cups must also be drained manually in order to remove the cleaning agent from the nipple or cup cavities.

**Cleaning a stable that is in use**

When cleaning a stable that is in use, first add 50 ml Aqua-clean or Hydrocare per 1000 litres water.

Starting with larger doses can cause two problems:

1. A decrease in water intake
2. If much dirt is present in the drinking water system, too much dirt will loosen at the same time, possibly leading to blockages.

For stables in use, it is better to start with a dosage of 50 ml per 1,000 litres (0.005%). The dosage can always be increased a bit, as indicated below, to a maximum of 250 ml per 1000 litres of water. Dosages higher than 250 ml per 1000 litres can lead to decreased water intake by the animals due to the diminished taste of the water.

**Cleaning while administering medication or between different drinking water supplements**

The mixing of different drinking water supplements should always be avoided. Cleaning agents or other drinking water supplements can influence, for example, the response time of antimicrobials. There are also unknown interactions between different drinking water supplements. It could happen that antimicrobials lose their efficacy when used simultaneously with a different supplement. Since there is no water consumption at certain moments of the day (at night, for example),
it is possible to keep the drinking water system filled with an Aqua-clean or Hydrocare solution during these times. For example, the administration of medication via the drinking water can be stopped at 7:00 p.m. Simply provide ordinary water for half an hour. Then an Aqua-clean or Hydrocare solution of 250 ml per 1000 litres can be added to the drinking water. The solution remains in the drinking water system for the entire night and thus has a long time to work.
Before the animals again drink in the morning, normal water should be supplied for half an hour in order to remove the Aqua-clean or Hydrocare solution from the drinking water system.
Then medication or a different supplement can be added to the drinking water.

# PART III ANTIMICROBIALS

## 1. Introduction

Administering antimicrobials through drinking water has many advantages. It is for instance easier to change the dosage during the medication period and it is easier to change the product choice in case initial treatment shows to be less effective. Because of these many advantages there is a tendency of antimicrobials being used more in drinking water than in feed and the expectation is that this tendency will spread throughout Europe. However, administering antimicrobials via the drinking water can cause problems such as clogged piping or drinking nipples.

## 2. Advantages and disadvantages of oral administration

Antimicrobials can be administered orally in different ways. The following table Advantages and disadvantages of the different ways of administering antimicrobials orally describes these.

**Table: Advantages and disadvantages of the different ways of administering antimicrobials orally.**

| | Advantages | Disadvantages |
|---|---|---|
| Premix | • not labour intensive for the livestock breeder<br>• the veterinary medicine is homogeneously mixed throughout the feed<br>• certainty that the treatment will be concluded | • influence on the daily routine of the mixed feed industry<br>• risk of cross contamination at the mixed feed company and on the farm<br>• 48 hr interval between prescription and start of treatment<br>• duration or dosage of the treatment cannot be adapted in the meantime<br>• livestock breeder is less aware of the treatment process |
| Top dressing | • duration or dosage of the treatment can easily be adapted<br>• individual treatment possible<br>• short interval between prescription and start of treatment<br>• livestock breeder is more aware of the treatment process | • labour intensive<br>• non-homogeneous mix<br>• variation in biological availability<br>• risk of cross contamination on the farm |
| Drinking water | • not labour intensive for the livestock breeder<br>• duration or dosage of the treatment can easily be adapted<br>• short interval between prescription and start of treatment<br>• broad range of antimicrobials is available<br>• livestock breeder is more aware of the treatment process | • good drinking water system is necessary<br>• good drinking water quality is necessary<br>• solubility and stability of the antimicrobials is a precondition |

Source: Dechra Veterinary Products

Drinking water medication is the most efficient and safest way to treat a herd of animals if the facilities are optimum. The water intake of sick animals is greater and longer in comparison to feed. This provides a greater guarantee concerning the medicine intake in most sick animals. The ability to directly administer medication can have a preventive effect among animals not yet infected. Moreover, the speed of absorption in the body of dissolved medication is greater than that of medication incorporated into the feed.

## 3. Possible interactions between antimicrobials and parameters in the drinking water

Antimicrobials can interact with parameters in the drinking water such as calcium and iron. Many (but not all) antibiotic products contain carrier substances such as lactose which leave remnants behind in the water pipes that serve as a breeding ground for microorganisms. Hence, antimicrobials without lactose are preferred. The extreme growth of the bacteria can clog piping and drinking nipples.

The following paragraphs describe the solubility and potential interactions with calcium and beta-lactamase producing bacteria for a number of antimicrobials.

## Tetracyclines

As such, in non-formulated preparations, tetracyclines do not dissolve well in water. The tetracycline with the poorest dissolvability in water is chlortetracycline.

After oral administration, tetracyclines are principally reabsorbed via the stomach and the duodenum. The absorption of tetracyclines is better in fasting animals than in non-fasting animals. Absorption is optimum with an acid pH.

With calcium, magnesium and iron, tetracycline complexes can form that interfere with the absorption from the gastrointestinal tract. These complexes can also clog the drinking water system. This is the case with oxytetracycline. Doxycycline does this to a lesser degree. Tetracyclines are not sensitive to beta-lactamase producing bacteria. The following table *Biological availability of oxytetracycline and doxycycline* indicates the biological availability of oxytetracycline and doxycycline.

**Table: Biological availability of oxytetracycline and doxycycline**

| | Oxytetracycline | Doxycycline |
|---|---|---|
| Pig | 3-5 % | 50% |
| Horse | Less than 1% | |
| Dog | 35% | 50% |
| Chicken | | 50% |
| Non-ruminating calf | | 50% |
| Turkey<br>- fasting<br>- with feed | <br>45%<br>10% | |

Source: FIDIN

## Trimethoprim-sulfa

Trimethoprim-sulfa is difficult to dissolve in water. Trimethoprim-sulfa will remain stable in a changing pH, unless the pH drops to below 4. Trimethoprim-sulfa does not bind to calcium and is not sensitive to beta-lactamase producing bacteria.

## Ampicillin and amoxicillin

Ampicillin and amoxicillin are very sensitive to fluctuations in temperature. Moreover, ampicillin and amoxicillin are sensitive to beta-lactamase producing bacteria that can be present in the drinking water system. Beta-lactamase producing bacteria neutralise amoxicillin and ampicillin.

Ampicillin and amoxicillin do not react to calcium, and only dissolve in an alkaline environment. Increasing the pH of the drinking water increases the solubility of these antimicrobials, but decreases their stability.

# 4. Interactions of antimicrobials, drinking water quality and drinking water system

## 4.1 Effect of drinking water quality on antimicrobials

Drinking water quality can have an effect on antimicrobials. Calcium for example binds to oxytetracycline. On farms with hard water, extra acid can be added to bind the calcium. The calcium then reacts with the acid, making the oxytetracycline freely available. The same applies to sulfonamide that is bound by organic substances. Additional interactions between antimicrobials and drinking water quality are described in chapter 3 *Possible interactions between antimicrobials and parameters in the drinking water*.

## 4.2 Effect of antimicrobials on drinking water quality

Pharmacists add taste correctors to sulfonamides in order to mask the bitter taste. Practicing veterinarians, however, indicate that sulfonamides still often add a taste to the water, despite the presence of taste correctors. Levamisol also has a bitter taste and results in decreased water intake. When calculating a solution of sulfonamides and levamisol, it is best to take into account possible decreased water intake.

## 4.3 Effect of antimicrobials on a drinking water system

Sometimes the addition of antimicrobials can result in a sort of slime that clogs the drinking nipples, possibly blocking the flow completely. The cause is a combination of the antibiotic and the quality of the drinking water system.

Drinking water always contains a number of types of bacteria, moulds and yeasts. The amounts are so small that no problems result. Adding medication to the drinking water kills most of the bacteria and some of the moulds and the yeasts. Consequently, the remaining bacteria are able to grow quickly, thereby clogging the drinking water system. Amoxicillin in particular can result in slime within a few hours.

In addition, the carriers of medication are often sugars. If after medicating, the water piping is not cleaned and disinfected properly, microorganisms such as moulds and yeasts can grow excessively on these remaining sugars. Hence, the use of antimicrobials without lactose is recommended, and a clean drinking water system before and after the treatments is essential. When using medication that can clog the drinking nipples more quickly, it is advisable to also clean and disinfect the piping during the treatment. For notes on cleaning during the treatments, see section 4.6 of Part II *Points to keep in mind when cleaning*. Cleaning agents with a light disinfecting action remove the slime-forming bacteria, eliminating the need for additional disinfection. For more information on cleaning drinking water systems, reference is made to Part II of the manual, chapter 4 *Cleaning and disinfecting drinking water systems.*

## 4.4 Points to keep in mind when medicating drinking water

When administering antimicrobials via the drinking water, attention should be paid to the following points:

- Allow the drinking water medication to circulate through the water pipes so that directly medicated water is available to the pigs.
- When not medicating; allow the rear section to drink from the medicine piping so that circulation remains. Ensure that the piping is clean and free of medication.
- Also clean the bucket or jerry can used for the solution in order to remove deposits and remnants.

## 5. Solutions

There are several water-soluble antimicrobials available. These water-soluble antimicrobials should be fully soluble in water and remain stable in the solution, without causing deposits.

An amoxicillin product, for example, dissolves very fast and stays stable in solution due to its special pharmaceutical composition.

Doxycycline and oxytetracycline only dissolve in an acid environment. If the water pH is too high, this can be remedied by acidifying the water. Then the antibiotic can be added. When simultaneously adding acids with antimicrobials, for example, consideration should be taken of possible effects on response times. Hence, it is important to follow the recommendations of the antibiotic manufacturer. When acidifying the water, consideration should be taken that possible dirt present in the piping can loosen and clog the drinking nipples. Viewed from a legal perspective, each addition represents a magistral preparation. There are veterinary medicinal products on the market that are ready to use, (including the correct proportion of acid).

Most antimicrobials remain effective in a solution for 24 hours. For optimum antibiotic efficacy, it is recommended to change the solution twice per day instead of only once, depending on the antibiotic used. A solution of amoxicillin, ampicillin and colistin, however, usually retains its effectiveness for no more than 12 hours. Without conditioning agents or at high antibiotic concentrations, the stability of amoxicillin and ampicillin in the solution decreases to as low as 2 - 4 hours.

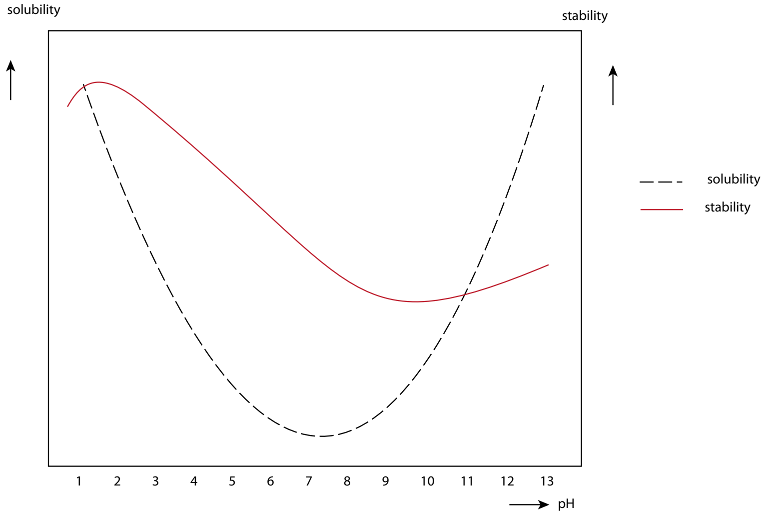
When preparing the solution, the following points are important:

1. Water temperature
2. Water supplements
3. Solution concentration
4. Solution shelf-life

The solution should be prepared in cold to lukewarm water. The medication appears to dissolve more quickly in hot water, but when the solution reaches room temperature, the medication often forms deposits or flakes.

The solubility of antimicrobials can sometimes be improved by changing the pH of the drinking water.

**Diagram: Tetracycline solubility**




Source: Dechra Veterinary Products

The diagram above *Tetracycline solubility* shows the stability and solubility of tetracyclines. Solubility is good at a high and low pH. Stability is best at a low pH. A concentrated tetracycline solution only remains stable at a low pH. Sometimes an acid may need to be added to a solution.

The dosage and duration of the treatment should be determined accurately. When the dosage is calculated and the solution has been prepared, the metering pump needs to be configured. The water intake of the animals to be treated needs to be accurately monitored. If necessary, the dosage can be changed the following day. At the end of each treatment, the livestock breeder and veterinarian together should evaluate the effect of the treatment. The amount of the antimicrobials required for a solution is shown in appendix 7 *Calculating the amount of antimicrobials in a solution*.

# PART IV SoluStab®

## SoluStab®

### Every drop perfectly balanced

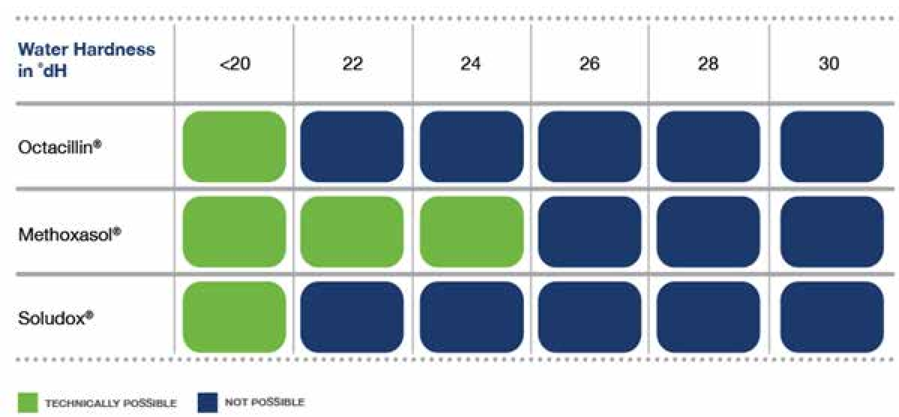
**SoluStab®** is a premium range of lactose free water-soluble products with a unique formula providing an optimal balance between solubility and stability.

The solubility and stability both are depending on pH. On top of that pH, hardness and buffering capacity of water varies and may change over time.

Ideally water medication products should be suitable for use in water with varying characteristics.

**SoluStab®** products contain the right amount of the right buffer. They are able to generate and maintain the right pH for the active ingredient for **at least 12 hours**.

**SoluStab®** products can be used in water with **pH between 5 and 8** and hardness up to 20° dH.



## SoluStab®

## Every drop perfectly balanced

### Lactose free

Tap and well water always contain bacteria, although mostly in low numbers.

However, their numbers can increase dramatically when there is an abundant source of energy. Adding products to the water that contain sugars (eg. lactose) can lead to excessive growth of bacteria and the formation of biofilm.

Biofilm is a slime caused by bacteria in the water that can:

- block nipples and pipes
- harbor resistant bacteria
- produce enzymes that degrade certain antimicrobials

**SoluStab®** has a unique lactose free formula which reduces the risk of biofilm development.

### Solubility

As shown in the table below, most active ingredients are quite difficult to dissolve in water. Their solubility often depends on pH of the water.

| Molecule | Solubility | pH dependency |
|---|---|---|
| **Tetracyclines** | Chlortetracycline is the poorest Doxycyline has much better solubility | Dissolve at low and high pH |
| **Trimethoprim Sulfa's** | Difficult to dissolve | Dissolve better at high pH |
| **Amoxicillin** | Difficult to dissolve, low solubility | Dissolve better at high pH |
| **Sodium Salicylate** | Dissolve easily | - |

### Stability

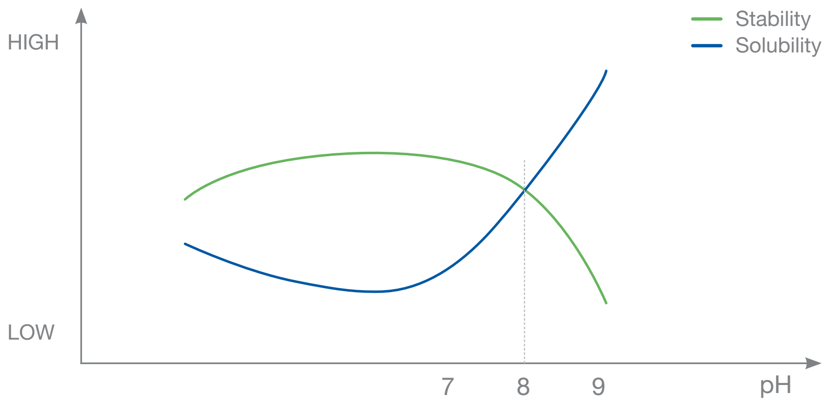
Once the product is dissolved the active ingredient has to stay active. For some molecules (doxycycline, amoxicillin) this is also depending on pH of the solution.

Because the pH of a solution can change over time (due to exposure to oxygen in the air) it is important to have sufficient buffering capacity in the solution.

**Optimal balance**

Unfortunately the pH required for the best solubility and best stability sometimes conflict. This is true for amoxicillin (see graph below):

- Solubility typically is only 1-2 gram/L but can be increased significantly by increasing the pH.
- This however will severely decrease stability: the solution will remain clear but the active ingredient will completely disappear within hours.



**Benefits of SoluStab®**

- Easy to use:
  - dissolves fast
  - no repeated or continuous stirring
- Optimal balance between solubility and stability
  - maximum efficacy with minimal waste.
- Unique lactose free formula:
  - reduced risk of biofilm development.
- Reduction of labour costs
  - no dealing with clogged pipes or nipples
- Supports the responsible use of antimicrobials
  - correct antibiotic concentrations at drinking nipple level

SOLUSTAB®

**EVERY DROP PERFECTLY BALANCED**

# PART V APPENDICES

## Appendix 1:
## Description of different purification processes for drinking water

### 1. Ion exchanger

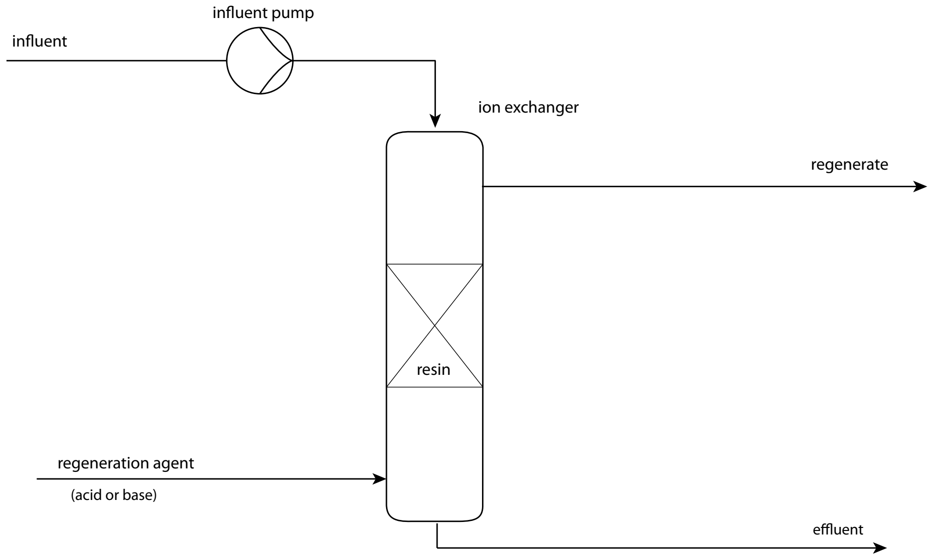
Ion exchange is the process of binding ions in a solution with a solid substance in contact with this liquid (the ion exchanger) and replacing these with a similar number of different ions (counterions) with the same charge, which are emitted by the ion exchanger.

These can be ions with a positive charge (cations) or a negative charge (anions). Ion exchange is a reversible process; no essential change in the structure of the solid substance takes place. The ion exchanger can be a salt, acid or base in solid form that is nonsoluble in water, but which itself contains water. This water is located in the porous resin beads. The so-called ‘steeping liquors’ sometimes constitute more than 50 percent of the total mass. The exchange reactions take place in this water phase, the steeping liquors. Ion exchange reactions are stoichiometric, which means that for each ion that is taken from the solution, one equivalent of a different ion is freed from the resin and returned to the solution.

Every substance that is split into ions can in principle undergo an ion exchange reaction with an ion exchanger.

The waste product generated by an ion exchange is the regenerate, a concentrated acid or alkaline solution of the removed component(s). The diagram below How an ion exchanger works, briefly describes the ion exchange.

**Diagram: Working mechanism of an ion exchanger**




Source: www.watertechnowijzer.nl

The **advantages** of an ion exchanger are:

- Treated water has a high level of purity
- The possibility to increase the concentration of ions in low concentrations
- Relatively small amount of space required
- In the case of complete processes, recovery is possible

The **disadvantages** of an ion exchanger are:

- An installation is needed to treat the regenerate
- The process uses chemicals
- The process is very sensitive to external influences
- The high cost of the ion exchanger

## 2. Aeration/degassing

Aeration/degassing is the process in which water is brought in close contact with air in order to change the amount of substances and gases dissolved in water. In the treatment of groundwater, it concerns increasing the level of oxygen and lowering the level of carbon dioxide, methane, hydrogen sulphide and volatile organic compounds. In this process, there is an exchange of substances and gases in which aeration/absorption (substance/gas to water) and degassing/desorption (substance/gas to water) always take place simultaneously.

The close contact between air and water required for aeration can be obtained using various systems:

- by allowing the water to fall through the air in fine drops (spraying)
- by dividing the water into thin layers (aeration towers, cascades)
- by allowing air to rise through the water in small bubbles (aeration wells, aeration plates, aeration compressors).

Technically these systems can be implemented in many ways. The choice of a specific implementation depends largely on the substances/gases to be removed.

## 3. Filtration process

In the filtration process, the water flows from above to below through a filter bed, usually sand of a more or less identical diameter. When filtering groundwater, the diameter of the filter material should be chosen based on the substance to be removed. A smaller diameter results in a larger contact surface for chemical and biological processes, and in improved filtering for catching and retaining particles. A larger diameter results in a more constant load over the thickness of the filter bed and lower hydraulic resistance, and thus in longer times before the filter clogs and needs to be rinsed.

In cases of higher levels of contamination (high levels of iron and ammonium), a larger diameter should be chosen, with post-filtration possibly used to catch the rinsed particles.

Thus, the diameter of the filter material must be located between narrow limits. When rinsing a filter, the smaller filter material rises back to the top because these particles have a lower ‘settling speed’. Thus, the finest filtering material is determinative for the clogging at the top of the filter, because the contamination is also the greatest there due to high levels of iron deposits.

For an identical filtering material diameter, the proportion between the upper and lower limit of the material (90%) should be smaller than 1.5 (fine sand) to 1.2 (coarse sand). Filter material is made by sifting sand or crushed gravel between two filters with a mesh that conforms to the upper limit or the lower limit. The diameter of the filter material and the filtering speed are related to the thickness of the filter bed. The filter bed thickness must be large enough to allow all chemical and bacteriological processes to (almost) fully complete. To be sure, these processes mainly take place in succession, but the zones in which the processes take place largely overlap. An incomplete process results in contamination of the filter floor, requiring the entire filter to be disassembled for thorough cleaning.

A layer of water is located above the filter bed. Its thickness may not be too great, since a longer time between aeration and the filter bed results in more oxidation and hydrolysis of iron, and thus in quicker clogging of the filter’s upper layer.

A water thickness that is too small can result in underpressure in the filter bed, which can lead to degassing and thus to quicker clogging by gas bubbles.

The following design parameters apply filters:

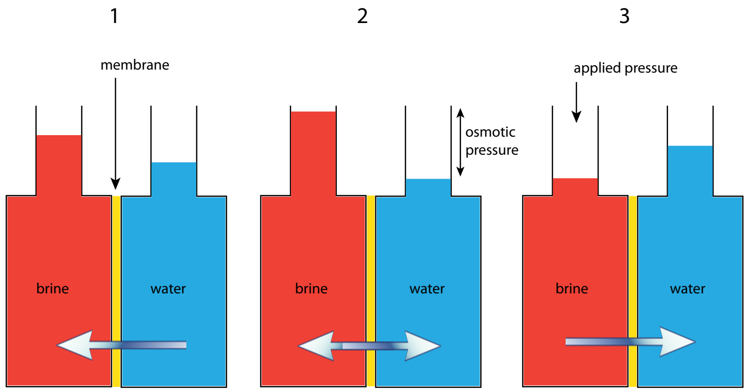
| | |
|---|---|
| • Particle diameter | 2.0 - 2.5 mm (coarse)<br>0.8 - 1.2 mm (fine) |
| • Bed thickness | 1.5 - 2.5 m |
| • Filtering speed | 5 - 7 m/hr |
| • Water layer thickness | 0.3 - 0.5 m |

## 4. Reverse osmosis

Reverse osmosis is based on the fact that systems seek equilibrium. Two liquids with different concentrations of dissolved salts, bacteria and viruses that come into contact with each other mix until there is a uniform concentration. When these two liquids are separated by a semipermeable membrane (the liquid is able to pass through the membrane, but not the salts, bacteria and viruses), the liquid with the low concentration moves through the membrane to the liquid with the high concentration.

After some time, the level of the second liquid is higher than that of the first liquid. This difference in height is called 'the osmotic pressure'. By making the pressure of the highest column of liquid greater than the osmotic pressure, the opposite effect is obtained, namely: 'reverse osmosis'. The liquid is forced back through the semipermeable membrane, while the salts (such as sodium, chloride and sulphate), bacteria and viruses remain behind (see the following diagram: Reverse osmosis). This removes a large part of the dissolved salts, bacteria and viruses from the water.

**Diagram: Reverse osmosis**




Source: www.lenntech.com

**Diagram: Reverse osmosis**

1. Water flows from a low concentration of salts, bacteria and viruses into a high concentration.
2. Osmotic pressure is the pressure needed to stop the water flow and create an equilibrium.
3. Applying pressure that is greater than the osmotic pressure reverses the water flow; water flows from a higher concentration of salts, bacteria and viruses into a lower concentration. This process is called 'reverse osmosis'.

The purification begins when the water is routed through a prefilter. Then pressure is applied and the water is forced through the ‘reverse osmosis membrane’. The water molecules dissolve in the surface of the membrane, allowing them to pass through the membrane. That which remains is residual water and the contamination. This water is removed. Of the 90 litres of water that is forced through the membrane, 30 litres of pure osmosis water remains for use. The device is regenerating, which means that there is a continuous discharge of harmful substances and microorganisms.

The prefiltering of the supply water for a reverse osmosis installation has a major effect on the installation’s performance. The required prefiltering depends on the quality of the supply water. The goal of the prefiltering is to reduce the level of organic material and bacteria, and hus to lower the MFI (Modified Fouling Index).

The level of organic substances and bacteria must be as low as possible in order to prevent so-called biofouling (unwanted growth of organisms) of the membranes. The installation of a prefiltering system has the following advantages:

- Longer membrane life
- Possible longer production time of the installation
- Easier operation
- Less personnel expenses.

Reverse osmosis is a technique that removes all the ions from water. Only gases dissolved in the water (methane, hydrogen sulphide and carbon dioxide) are not removed. These must be removed separately by means of an Aeration and Degassing Tower. Hydrogen sulphide can also be removed from the water using a deferrization installation.

## Appendix 2:
## The purification process per parameter

### Softening

How an ion exchanger works is explained in appendix 1 *Description of different purification processes for drinking water*.

Softening drinking water for livestock removes calcium and magnesium ions from the water. These ions are responsible for calcium and other deposits (also called scaling). The most often used ion exchanger for softening water is a strongly acidic cation exchanger in the $Na^+$ form. The water's pH does not change during the softening process. A sodium chloride salt solution is used for the regeneration (returning the cation exchanger to its original condition). The brine solution used for the regeneration will contain calcium, magnesium and sodium ions after the process is complete. The regeneration liquid containing chloride is drained into the sewer.
In this, it is important to ensure that specific discharge standards are not violated, especially the chloride standard.

When regenerating, the loaded resin is reactivated, thus restoring the exchange capacity.

A major disadvantage of the use of sodium chloride is that the salt content in the water increases considerably. A major change in the drinking water's salt content results in decreased water intake, due to the changed taste of the water. If the water's taste changes, it is advisable to partially desalt the water after the softening process.

A water softener also often removes manganese and ammonium from the water

## Deferrization

Iron is removed from the drinking water via aeration (oxidation) and filtration. A detailed description of the aeration and filtration processes can be found in appendix 1 *Description of different purification processes for drinking water.*

Most deferrization installations convert the iron II salts (Fe2+) into in iron III salts (Fe3+) under the influence of compressed air (spraying). The injection of oxygen results in the almost immediate oxidation of dissolved iron into iron III salts, causing iron deposits on the walls and piping of the distribution system. To limit the deposits, downward spraying is preferred, directly above a filter (for example a sand or gravel bed). Contamination will always occur in the distribution system and the sprinklers, which will negatively affect proper distribution and spraying. Because of this, sprayer systems will need to be cleaned several times per year.

Hence, iron reactions can already take place during the aeration. On the one hand, this is positive since the oxygen used here is supplemented further, and the CO2 formed here is still (partially) removed. On the other hand, the iron flakes created here are more difficult to filter than iron flakes that arise and grow in the filter itself.

The reaction of the oxygen with the iron should take place in the filter as much as possible.
The iron flakes are usually trapped in the upper 0.3 – 0.5 metre of the filter bed. The deposits are always easily identifiable by their rust brown colour.

The speed at which the reaction into iron III salts takes place depends strongly on the pH.
The process is slower with a low pH than with a high pH. The total reaction of iron forms acids, thereby slowing down the process. In practice, the pH of the water is usually such that a quick reaction is possible, while the acid formed reacts with the HCO3 present in the formation of CO2, causing the pH to decrease only slightly.

A disadvantage of deferrization installations can be that if the aeration is too strong and the ammonium level of the water is high, under the influence of iron the ammonium is converted to harmful nitrite. Proper tuning of the installation is thus very important.

In certain types of ground surface (boggy ground), the iron is strongly bound to an organic substance. In this case, it is difficult to free the iron and allow it to oxidise with air into iron III salts. Even with the use of a deferrization installation, the water will still contain iron. However, this causes few problems in the drinking water installation, since the iron concentration is often not high.

### Removing manganese

Manganese can be removed from drinking water via aeration (oxidation) and filtration. A detailed description of these processes can be found in appendix 1 *Description of different purification processes for drinking water*.

Aeration causes only a slow oxidation into MnO2 as long as the pH is less than 8.6. In the case of a low pH, the oxidation of manganese can be quickened by using a filter bed consisting of granules surrounded by pyrolusite. This filter material is obtained for example by treating greensand (bare sand) with manganese II sulphate and then with potassium permanganate, so that a film of manganese oxide forms on the greensand grains. These oxides also give off part of their oxygen in the oxidation reaction, so that polyvalent manganese oxide compounds must sometimes be regenerated by potassium permanganate. Deposits of iron, calcium carbonate and organic substances reduce the activity of the polyvalent manganese oxide compounds; thus when using this method, it is best to remove the iron beforehand. Since the manganese dioxide deposits attach themselves to the grains of the filter bed, the speed of the manganese removal increases once the reaction has begun.

The black colour shows that manganese is deposited in the lowest part of the filter. In addition, in the filtering action, the manganese removal only gains momentum as the ammonium removal is already substantial. The manganese deposits are difficult to rinse away, since the bonding with the grains of sand is quite strong. Due to the manganese deposits, the filter material must be replaced regularly (sometimes even yearly), or thoroughly cleaned.

## Removing ammonium, nitrite and nitrate

In the deferrization installation, ammonium is deposited in the middle of the filter bed, under (after) the iron deposits. A precondition for the ammonia deposit is that sufficient biomass has been deposited in the filter. This can sometimes take weeks, such that filters with new filter material must first be ‘broken in’ before good filtering quality is obtained.

For ammonium removal, good ‘management’ of the biomass is of major importance. In the case of intensive rinsing, the amount of biomass can be too small and in the case of too careful rinsing, biomass can accumulate. The latter results in the growth of other bacteria such as Aeromonas and even in the development of anaerobic zones in the biomass itself.

In addition, major fluctuations in the ammonium supply (flow rate and concentration) to the filter must be avoided. Despite good biomass management, the filter material should be replaced or cleaned each year.

## Appendix 3:
## Available drinking water tests

Various tests can be performed to determine water quality.
The most common drinking water tests on livestock farms are:

- The bacteriological study
- The chemical study
- The organoleptic (aesthetic) study

**The bacteriological study**

The following parameters can be tested in a bacteriological study:

- The aerobic bacterial count in 100 cfu (colony forming units)/ml
- The coliform bacteria (enterobacteriaceae) in cfu/ml
- The enterococci in cfu/ml
- The E. Coli bacteria in cfu/ml
- Moulds
- Yeasts
- Salmonella
- Clostridium

Often tests are only performed for the aerobic bacterial count, coliform bacteria and moulds and yeasts. In the case of an increased coliform bacterial count, it is advised to also test for enterococci. Enterococci indicate recent contamination.

## Chemical study

A chemical study tests among others the following parameters:

- Ammonium Sodium
- Nitrite Chloride
- Sulphate Nitrate
- Hardness
- Iron
- pH
- Manganese

## The organoleptic study

An organoleptic study tests among others the following parameters:

- Smell
- Colour
- Taste
- Turbidity

A chemical study tests for the concentrations of the parameters iron, manganese, sodium and sulphate. These parameters are also tested in the organoleptic study, because they affect the taste, smell, colour and turbidity of the drinking water. In addition, the organoleptic study can also determine the concentration of zinc in the water. Zinc also affects the smell, colour, taste and turbidity of the water.

# Appendix 4: Parameters

## Hardness

The hardness of water is determined by the presence of soluble salts of alkaline earth metals (hardness elements), of which only calcium and magnesium salts are important. By nature, calcium and magnesium are present in groundwater and surface water and thus also in drinking and process water. Both salts enter the groundwater while the water is in the ground: substances from the ground dissolve in the groundwater. Calcium and magnesium can also enter via discharges into the surface water. The degree to which these are present in the water varies strongly from place to place, and from source to source.

### The unit in which water hardness is expressed

Water hardness is generally expressed in (milli)moles per litre (mmol/l). By definition, the hardness of water is the sum of the amounts of calcium and magnesium, expressed in mmol/l. Water with a total hardness of less than 1.5 mmol/l is considered 'soft' water. Hardness between 1.5 and 2.5 mmol/l is considered average. Water with values greater than 2.5 mmol/l is considered 'hard' water.

Sometimes hardness is expressed in German hardness degrees (°D). The amounts of calcium and magnesium are then converted to the corresponding amount of CaO (calcium oxide). The number of parts of CaO in 100,000 parts of water yields the hardness in °D. 1 °D is equivalent to 10 mg CaO/l. When applying this scale, several categories are used.

The various categories are indicated in the following table: .

**Table: Water hardness**

| °D | Classification of water hardness |
|---|---|
| 0 - 4 | Very soft water |
| 4 - 8 | Soft water |
| 8 - 12 | Average |
| 12 - 18 | Rather hard water |
| 18 - 30 | Hard water |

Source: Water in de industrie, The Hague: ten Hagen & Stam publishers, 2001

Generally speaking, water should not be too hard, but also not too soft. Water that is too hard results in undesirable deposits. Soft water contains insufficient calcium and magnesium ions to form a calcium layer on the inside of water piping. This calcium layer is desirable because it protects the water piping against corrosion. The Water Supply Decree indicates a lower limit of 8.6 °D.

## Types of hardness

Water hardness can be divided into two categories: permanent hardness and temporary hardness.

1. Permanent hardness is the hardness that remains after the water is boiled for a long time.

2. Temporary hardness is the difference between the total hardness and the permanent hardness. When heated (or in the case of a higher pH), bicarbonate ions are converted to carbonate ions. In the presence of calcium ions, bicarbonate ions are able to dissolve only in very low concentrations and form calcium carbonate deposits.

Temporary hardness is very undesirable in water pipes because most calcium deposits form due to this. Calcium deposits can among others result in clogged piping.

## Iron

By nature, iron ions are present in groundwater and surface water. Iron enters the groundwater while the water is in the ground: substances from the ground dissolve in the groundwater. Iron can also enter via discharge into the surface water. The degree to which iron is present in the water varies strongly from place to place, and from source to source.

In the groundwater extracted in the Netherlands, iron appears in concentrations of a few milligrams per litre to special cases of 25 mg/l. Iron is present in raw (untreated) water generally in the form of iron bicarbonate. Iron also occurs in bound form (humic acids). Occasionally iron is also present in the form of iron sulphate.

## Manganese

By nature, manganese ions are present in groundwater and surface water and thus also in drinking and process water. Manganese enters the groundwater while the water is in the ground: substances from the ground dissolve in the groundwater. Manganese can also enter via discharge into the surface water. The degree to which manganese is present in the water varies strongly from place to place, and from source to source.

In drinking water, manganese usually is present together with iron, with both having identical bonds. The manganese concentration, however, is often less than the iron concentration. Dissolved manganese salts are more stable than the corresponding iron II compounds; the theoretical use of oxygen is approximately twice as high in the case of iron oxidation.

## Ammonium, nitrite and nitrate

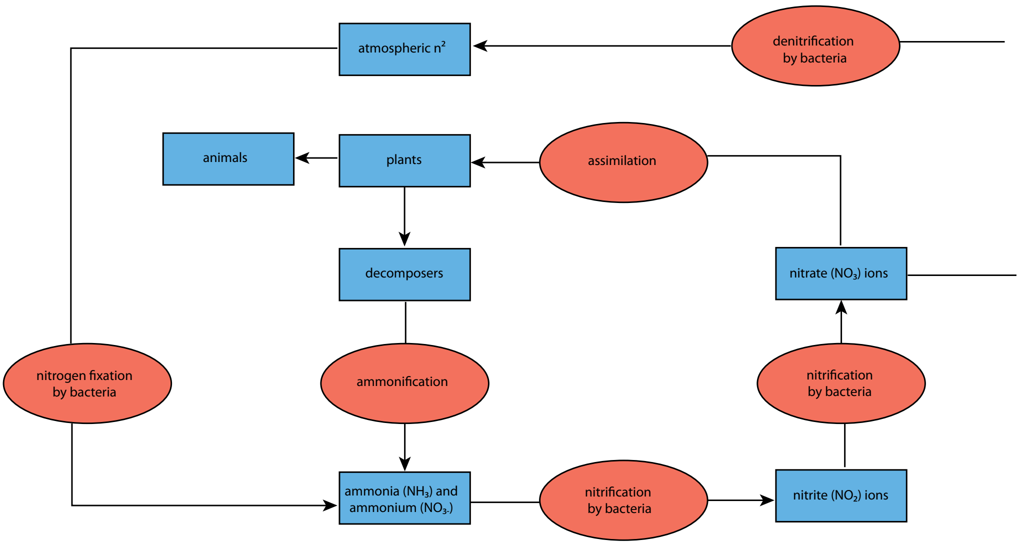
Ammonium is created during the decomposition of substances containing protein. Substances containing protein are present not only in living beings, but are also found in:

- Wood
- Manure
- Leaves

Ammonium is formed when little or no oxygen is present (anaerobic decomposition). The ammonium comes in contact with oxygen, then under the influence of an excess of oxygen (for example in a deferrization installation) or via aerobic bacteria, the reverse process takes place: conversion of ammonium into proteins via nitrite and nitrate (nitrification process).

A diagram of the nitrogen cycle is given below.

Diagram: Nitrogen cycle:




Source: www.lenntech.com

In the groundwater extracted in the Netherlands, ammonium appears in concentrations of a few milligrams per litre to as much as 10 mg/l in special cases.

## Sodium and chlorine

One of the most common salts is cooking salt (sodium chloride). When water is softened a specific crystallised from of sodium chloride is used that causes the formation of calciu chloride and releases sodium released. If drinking water has an abnormal Na proportion contains Cl (for example 300 mg/l Na and 45 mg/l Cl), it can be assumed that a softening installation is being used. With a Na : Cl ratio of 300 mg/l : 45 mg/l, the water hardness is under 5° D.

## Hydrogen sulphide and sulphate

Hydrogen sulphide (H2S) and sulphate (SO4 2-) are present in groundwater extracted in the Netherlands in concentrations of up to a few milligrams per litre. Hydrogen sulphide is a gas that has the characteristic smell of ‘rotten eggs’. When the gas evaporates, corrosive fumes are released. The gas is also very combustible and explosive when combined with air.

## pH

pH measures the concentration of free hydrogen ions (H+) and is also referred to as acidity.
The pH is one of the most important characteristics of water. Water is capable of dissolving almost all ions (maintaining in dissolved form). pH uses a logarithmic scale: when something becomes ten times more acidic (ten times more free hydrogen ions), the pH number decreases by one unit. In a substance 100 times as acidic, the pH decreases by two units. Thus, a liquid with a pH of 4.5 is 100 times more acidic than a liquid with a pH of 6.5.

# Appendix 5:
# Problems with parameters

## Hardness

There are different levels of calcium deposits:

1. The presence of calcium in drinking water is already a cause of deposits in the drinking water system.

- Limestone is another word for calcium carbonate.
  Calcium carbonate is formed in the reaction between the calcium and carbonate ions present in the water by nature:
  $Ca^{2+}$ + $CO3^{2-}$ ⇨ CaCO3 ⇩ T(CaCO3 forms deposits).
  Limestone forms deposits on the inside of the piping and in the drinking nipples from which the animals drink.

2. Heating water with high levels of hardness increases calcium deposits in the drinking water system.

- Most substances dissolve better in heated water. However, a number of substances, including calcium carbonate, dissolve more poorly in heated water. In pig stables as well as in broiler housing, the temperature is higher than the outside temperature, since these stables are heated. Water is transported from outside to inside via the piping, and thus is warmed in the stables. When water is heated, extra carbonate ions can be formed due to dissociation of the hydrogen carbonate present in water, according to the following reaction equation:
  $2HCO^{3}$ ⇦⇨$CO3^{2-}$ + CO2 ⇧ W(CO2 is released into the air) + H2O
  The concentration of carbonate ions increases, resulting in the above-mentioned reaction:
  $Ca^{2+}$ + $CO3^{2-}$ ⇨CaCO3 ⇩ will take place

## Iron

A concentration of iron in the drinking water greater than 2.5 mg/l causes clogged drinking nipples due to iron deposits. Iron deposits are caused by iron hydroxide ($Fe^{3+}$ salts). Due to aeration or when groundwater comes in contact with the atmosphere, iron ($Fe^{2+}$) reacts with oxygen and water, and forms into the released carbon dioxide and the undissolved iron hydroxide deposits. This reaction is reflected in the following comparison:
$4Fe(HCO3)^{2}$ + $O^{2}$ + 2H2O ◷ $4Fe(OH)^{3}$ ⇩ (forms deposits) + $8CO^{2}$ ⇧ (released into the air).

## Manganese

There are different levels of manganese deposits:

1. Water with manganese levels above 2.0 mg/l can corrode stainless steel and form deposits due to a reaction with oxygen in the water.

- Manganese undergoes a chemical bond with the stainless steel piping, causing blackbrown deposits on the inside of the piping. The black-brown deposits can suddenly dislodge, causing water pipes and drinking water systems to become clogged. This can also result in the decreased flow of water. Both situations result in a reduction in the amount of water available to the animal. Decreased water intake leads to reduced feed intake, and thus to decreased yield.
- Manganese reacts with oxygen in the water and forms manganese oxide (the reaction lasts approximately 25 seconds) causing a black, granular deposit. Deposits in the drinking water system lead to decreased water flow and can clog drinking nipples. Decreased water intake leads to reduced feed intake, and thus to decreased yield.

## Appendix 6:
## Checklist when testing drinking water systems

# EXAMPLE

## Checklist when testing drinking water systems

### *TO BE FILLED IN BY LIVESTOCK BREEDER / VETERINARIAN*

**Veterinary practice:** ..........................................................................................

Veterinary practice contact: ..........................................................................................

Name of livestock breeder: ..........................................................................................

Address: ..........................................................................................

City: ..........................................................................................

Type of farm: ..........................................................................................

Number of animals: ..........................................................................................

Sections: ..........................................................................................

Number per section: ..........................................................................................

Stables per section: ..........................................................................................

**Water usage** Tap water / well water *

**Purification systems**

| | | |
|---|---|---|
| | Deferrization installation | yes / no* |
| | Softening installation | yes / no* |
| | Reverse osmosis | yes / no* |

**Sampling** Date of sampling: ....................................(dd/mm/yy)

Take three samples of the drinking water.

| Locations | Tests | Performed |
|---|---|---|
| Source | Chemical and bacteriological | Yes / no* |
| Float tank/piping* | Bacteriological | Yes / no* |
| Drinking station | Bacteriological | Yes / no* |

**Inventory of drinking water supplements**

- ......................................................................
- ......................................................................
- ......................................................................
- ......................................................................
- ......................................................................
- ......................................................................
- ......................................................................
- ......................................................................

**Manner of cleaning**

Cleaning agent: ........................................................... Concentration: ................................................

Time needed for cleaning agent to work: ..........................................................................................

Cleaning frequency: ..........................................................................................

**Drinking water system**

| | | |
|---|---|---|
| Float tanks or break tanks | yes / no* | open / closed* |
| | accessibility: | ++ / + / ± / - / -- * |
| | hygiene: | ++ / + / ± / - / -- * |
| Connections to float tanks | Extend out into float tank | yes / no* |
| Bends and sags | Unnecessary bends | yes / no* |
| | Sagging piping | yes / no* |

* circle that which applies

Piping material*

| | |
|---|---|
| *Main piping* | Iron or galvanised iron / PVC / Polyethylene / Stainless steel |
| *Piping in the section* | Iron or galvanised iron / PVC / Polyethylene / Stainless steel |
| *Piping to which the animals have access* | Iron or galvanised iron / PVC / Polyethylene / Stainless steel |

| | | |
|---|---|---|
| **Plastic piping attached to steel pipe** | | yes / no* |
| **Drinking water pipes in the vicinity of heating pipe** | | yes / no* |
| **Dead-end piping** | | yes / no* |
| | Terminated with plug or drain tap | yes / no* |
| **Couplings** | iron | yes / no* |
| | Excess glue | yes / no* |
| **Piping diameter** | Unnecessarily large piping diameter | yes / no* |
| **Watering stations** | Water spillage | ++ / + / ± / - / -- |

Water flow nipples/drinking troughs in ml/min:

| | | | |
|---|---|---|---|
| 1st nipple | .................................... | 6 | .............................................. |
| 2nd nipple | .................................... | 7 | .............................................. |
| 3rd nipple | .................................... | 8 | .............................................. |
| 4 | .................................... | 9 | .............................................. |
| 5 | .................................... | 10 | .............................................. |

| | | |
|---|---|---|
| Hygiene at watering stations | | ++ / + / ± / - / -- * |
| | Possible to excrete into station | yes / no* |
| **Dosing equipment** | | yes / no* |
| | Mechanical / electric* | |

* circle that which applies

## *TO BE FILLED IN BY VETERINARIAN*

Assess abnormal water testing results based on the following criteria:

Location: Criteria: Result:

..........................................................................................................................................................

..........................................................................................................................................................

Cause of the problem:

..........................................................................................................................................................

..........................................................................................................................................................

Solution to the problem:

..........................................................................................................................................................

..........................................................................................................................................................

Recommendations to avoid the problem in the future:

..........................................................................................................................................................

..........................................................................................................................................................

## Appendix 7:
## Calculating the amount of products in a solution

### Water intake is highly influenced by

- Climate
- Feed composition (up to 50% increase is possible!)
- Disease
- Water taste

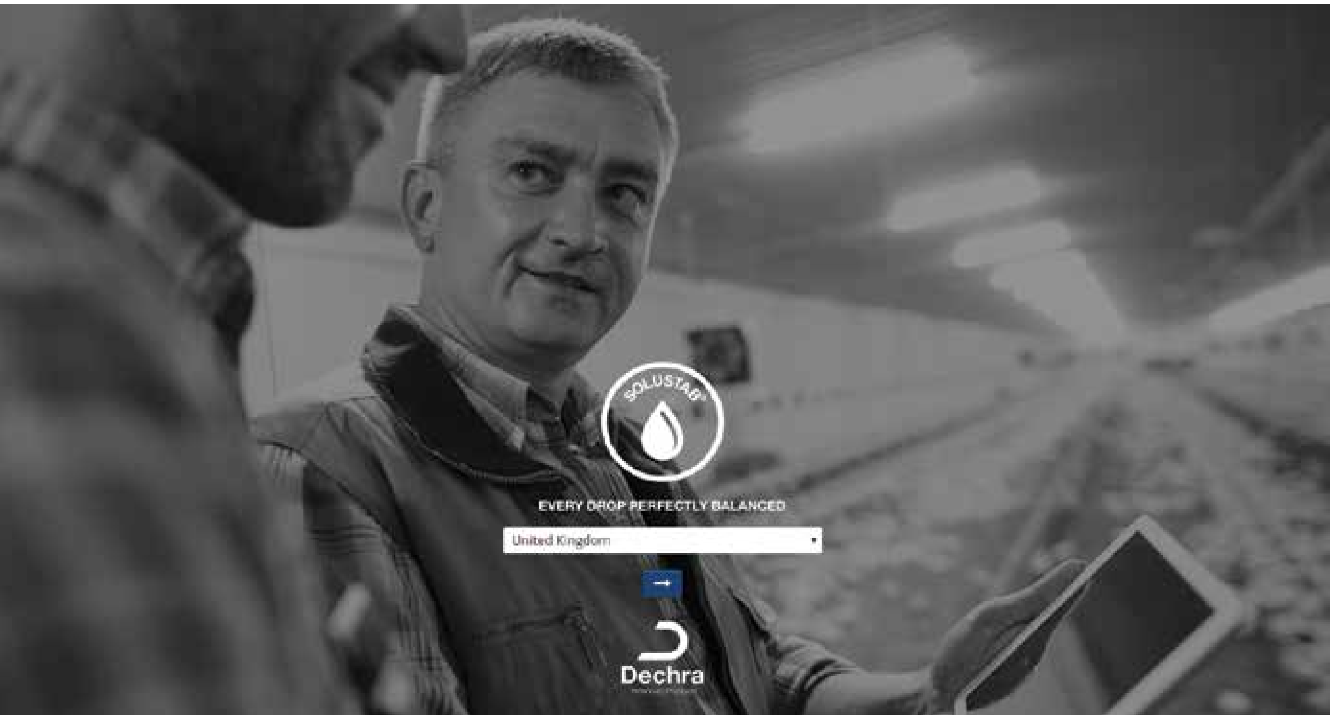
Note
Ideally install water flow meters per compartment and use the actual water intake in the calculations. Always check if the stock solution is fully consumed in time.

### Accurate dosing is crucial

| | |
|---|---|
| Overdosing | -> unnecessary use of antimicrobial products<br>-> waste of money |
| Underdosing | -> potential lack of efficacy<br>-> increased risk of resistance development |

To calculate the right amount of product in a solution Dechra has developed the SoluStab® Calculator to be found online on: calculator.SoluStab.eu

- Easy to use
- Helps preventing mistakes
- Supports responsible use



## Appendix 8:
## Reference values for quality drinking water

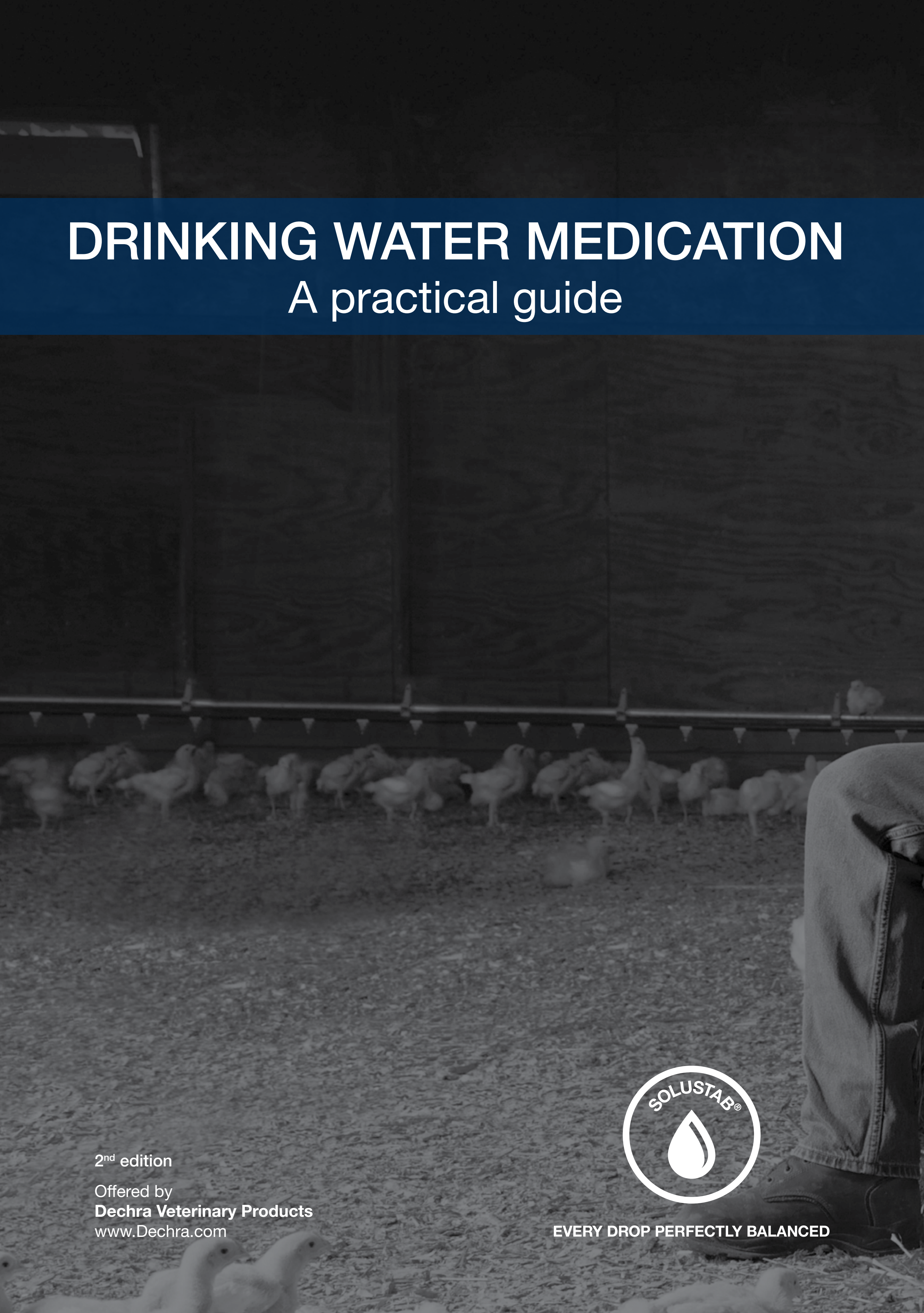
The table below: Drinking water standards for pigs and poultry, contains the normal and critical values used by the (Dutch) Animal Health Service when assessing the suitability of drinking water. Check the results of the water samples against the following table:

**Table: Drinking water standards for pigs and poultry****

| Parameter | Pigs* | | Poultry | |
|---|---|---|---|---|
| | good | abnormal | good | abnormal |
| pH | 5 - 8.5 | <4 and >9 | 5 - 8.5 | <4 and >9 |
| Ammonium (mg/l) | <1.0 | >2.0 | <1.0 | >2.0 |
| Nitrite (mg/l) | <0.10 | >1.00 | <0.10 | >1.00 |
| Nitrate (mg/l) | <100 | >200 | <100 | >200 |
| Chloride (mg/l) | <250 | >2000 | <200 | >2000 |
| Sodium (mg/l) | <400 | >800 | <100 | >200 (1) |
| Sulphate (mg/l) | <150 | >250 | <150 | >250 |
| Iron (mg/l) | <0,5 | >10,0 | <0,5 | >5,0 |
| Manganese (mg/l) | <1,0 | >2,0 | <0,5 | >1,0 |
| Hardness (°D) | <20 | >25 | <15 | >20 |
| Hydrogen sulphide | not detected | | not detected | |
| Coliform bacteria (cfu/ml) | <100 | >100 | <100 | >100 |
| Total bacterial count (cfu/ml) | <100.000 | >100.000 | <100.000 | >100.000 |
| * Can also be used on horses and other monogastric animals<br>(1) for laying hens: > 400 mg/l sodium | | | | |

Source: Animal Health Service (Netherlands)

** The 'good' columns contain the values for which the animal species in question experiences no negative effects. The 'abnormal' columns contain the limits at which the animal species in question experiences negative effects.



# DRINKING WATER MEDICATION
## A practical guide

2nd edition

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