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Assessment of Bacteria and Physicochemical Parameters in Poultry Drinking Water in Skikda Region (Algeria)

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ABSTRACT

Background: Water is an essential nutrient for animals and therefore quality preservation is fundamental for good birds live in flocks.

Objectives: This study aims to evaluate the microbiological and physicochemical quality of poultry water among farms in the Skikda region of Algeria.

Methods: Fifteen samples were collected during March, 2019 to May, 2019 from 15 locations of both broiler and layer farms. The samples were processed for bacterial analysis such as total coliforms, faecal coliforms, faecal streptococci and, *Salmonella*. The same samples were also monitored for the levels of physico-chemical parameters and heavy metals.

Results: The diverse contaminations of the total coliforms, the faecal coliforms, and the streptococci, were noticed 53%, 13%, and 20% respectively. The analysis showed the absence of Salmonella in all analysed samples. The results for the totality of samples were of satisfactory in terms of pH, nitrate, chloride, copper dosage, cadmium, and lead. The study showed higher levels for physicochemical parameters like hardness (69,30±71,93°F), alkalinity (53,3507±61,1743), nitrates (0,7076±1,1605); and heavy metals such as iron (0,1568±0,2035), the cadmium (0,0056±0,0119) and the nickel (0,0256±0,0512) were found.

Conclusion: The quality of water analysed at these poultry farms is far from satisfactory and presents diverse contaminations by the coliforms and the streptococci, some physico-chemical properties and heavy metals.

Key words: Bacteriology, Heavy metal, Physical Chemistry, Poultry, Water

Introduction

Water, an essential element for life, is used for several purposes in poultry farming such as for the hydration of birds; regulating body temperature, aiding digestion, therapeutic vector (Medicaments and vaccines), and as a vehicle of antiseptics. It is also important for the quality of the product and the productiveness of breeding, but unfortunately, stockbreeders often do not give it enough attention. Although, the success of poultry farms largely depends on the quality of the drinking water distributed to the birds. Monitoring water consumption daily is shown to be a reliable measure of broiler performance. Therefore, both quantitative and qualitative analyses of water should be performed regularly because of the impact on the health and welfare of birds (Bobinienė *et al*., 2014).

In well-controlled farming conditions, the harmful effects of poor-quality water can pass unnoticed, but in poorly controlled conditions, the effects can manifest first on the health and production of the poultry (Amaral, 2004; Sheikh, 2019; Swelum *et al*., 2021). The effectiveness of antibiotic therapy can also be impacted as diseases can be transmitted to the flock through drinking water, particularly from water which is contaminated by pathogenic organisms. These pathogens generally originate from other animal species and man, such as in the case of *Salmonella* and *Escherichia coli*, respectively (Swelum *et al*., 2021; Levantesi *et al*., 2012; Cabral, 2010; Amaral, 2004).

Water is an essential nutrient for birds and therefore quality preservation is fundamental for good birds to live in flocks. It was established that it is an important factor in poultry raising because a bird can survive several weeks without food, but only a few days without water. Broilers drink a great deal of water and a critical fact that producers may not be aware of is that feed and water consumption are very closely related, for example, a 2.3 kg broiler will consume approximately 8.2 kg of water, compared to 4.6 kg of feed (Lacy, 2002; Tabler, 2003). Water, in addition to being a vital nutrient, is involved in many aspects of poultry metabolism including body temperature control, digestion and absorption of food, transport of nutrients, and the elimination of liquid, via urine, from the body (Bobinienė *et al*., 2014).

Drinking water comes from two main sources: surface water and groundwater. In the poultry industry, several water sources are used as safe drinking water in poultry farms; including tap water, filter water, roof tank water, and groundwater (Saleh *et al*., 2023). The use of water with adequate physical, chemical, and microbiological quality is of fundamental importance. Since many birds have access to the same water source, quality problems will affect a great number of animals. Poor quality water can not only cause many therapeutic failures but also, be a factor predisposing to reduce the effectiveness of vaccines and medications administered (Amaral, 2004; Swelum *et al*., 2021).

Agricultural production, such as livestock farming an important economic activity, is a major consumer of water for hydration as well as facility cleaning. Limited data is available concerning the levels and conditions of water used in livestock farms. This study aims to provide insight into the quality of the drinking water used in some poultry farms in the Skikda region (north-eastern Algeria), which has been previously revealed by several studies in other countries (Morocco and Libya) (El Allaoui et al., 2016; Kassem Agha et al., 2022).

The objective of this study was to assess the physico-chemical and bacteriological quality of the well water, used as drinking water for poultry, as well as its impact on health and production of birds.

Material and Methods

Study Area

The present study was carried out from March, 2019 to May, 2019 and included fifteen poultry farms. These poultry farms were further categorised into seven broiler farms, seven laying hen farms and a turkey farm located in the province of Skikda, Algeria. The province is exposed to Mediterranean climatological influences and contains 330 poultry farms registered with agricultural services. The breeding capacity of the studied farms were varied as 3500 birds for broiler farms and 5000 birds for laying hen and turkey farms. Given the importance of the number of farms, the technical and economic constraints of carrying out the survey, we limited ourselves to covering a few municipalities. The choice of poultry farms selection was guided by the free manager's acceptance to cooperate and their easy accessibility.

Data collection and sampling conditions

Each farm was visited once for the sampling. Water samples were taken randomly from five (05) drinking troughs used for the poultry. Samples were collected, using a sterile syringe, emptied into sterile 100 mL bottles. The samples were collected under the rigid conditions to avoid any accidental contamination.

All samples were placed on ice packs and transported to the laboratory, within a period not exceeding 2 hours. Samples were either treated on the same day or kept in the refrigerator overnight. The organisation of sampling in farms is shown in Table-1.

To facilitate the analysis and avoiding errors, all the samples were labelled and numbered properly. All the bottles were accompanied by a data sheet making the possibility of useful information for the laboratory such as date and nature of the sample, information on livestock and water supply. All information were collected in a livestock questionnaire.

Parallel to the collection of samples for physical, chemical and microbiological analyses, the farmers in this study completed a multiple-choice questionnaire validated by the authors of this paper that covered a variety of factors affecting water quality. The epidemiological questionnaire contained 30 closed-type questions. The latter was related to the location and conception of the rearing buildings, the broiler rearing characteristics such as equipment, environmental conditions, biosecurity measures, origin of chicks and feed, farm staff, vaccination programs, and use of antibiotics.

Bacteriological analysis

A total of 15 samples taken from 15 poultry farms were the subject of a bacteriological study aimed at counting total coliforms, faecal and streptococci as well as the search for *Salmonella.*

Bacteriological analyses were performed according to the standards protocols:

For the isolation of *Salmonella*, this study used the protocol of the International Organization for Standardization for Detection of *Salmonella* spp. in animal feces and in environmental samples from the Primary production stage, using buffered peptone water broth (PWB) (Fluka, Sigma Aldrich, France) for pre-enrichment solution, Muller-Kauffmann tetrathionate/novobiocin broth (AES Chemunex Combourg, France) and Rappaport Vassiliadis broth (Merck Darmstadt, Germany) for enrichment, XLD (Fluka analytical Steinheim, Switzerland) and Hektoen agars (Pasteur Institute of Algeria) for isolation (ISO, 2007)

Enumeration of *E. Coli* and coliform bacteria was done according to the AFNOR NF EN ISO 9308-3 standard (March 1999) of water quality detection and enumeration of *E. Coli* and coliform bacteria in surface and wastewater. This process was carried out in a liquid medium on BCPL (Pasteur Institute of Algeria) and indole mannitol medium (Schubert medium) (Pasteur Institute of Algeria) using general method by seeding in Most probable number (MPN) liquid medium (Search and enumeration of coliforms and thermo-tolerant coliforms) (AFNOR, 1999 a). The formation of a red ring on the surface of the positive tube (Schubert medium) after the addition of Kovacs reagent (Pasteur Institute of Algeria) showed the presence of *E. Coli*.

The enumeration of fecal streptococci was carried out according to the standard of the miniaturized method (most probable number) by inoculation in ROTHE medium (glucose broth with sodium azide) (Pasteur Institute of Algeria) and E.V.A (LYTSKI) (Pasteur Institute of Algeria); uses two tests (Presumptive and Confirmatory tests) (NF EN ISO 7899-1 March 1999/T 90-432). The final reading is also approved according to the prescriptions of MPN tables Standard Methods, 1989 (AFNOR, 1999 b).

Physico-chemical and heavy metals analysis

The physico-chemical analysis was carried out in the technical laboratory of the GL1K complex, SONATRACH of Skikda according to the methods approved by Rodier *et al.* (2016). The pH measurement was carried out by an electronic pH meter. The measurement of heavy metals such as Iron (Fe), Lead (Pb), Copper (Cu), Cadmium (Cd) and Nickel (Ni) were taken by atomic absorption spectrophotometry (Thermo Fishe2.r Scientific Inc, Waltham, Massachusetts, États-Unis) (Rodier *et al.*, 2016).

Determination of chlorides (argentimetry)

pH of the sample must be adjusted to 8.3 and, the titration will be done using a silver nitrate solution (Pasteur Institute of Algeria) in the presence of the indicator Bipotassium Chromate (K2CrO4) (Pasteur Institute of Algeria) we titrate until the color brick red.

Determination of TA and TAC alkalinity

The relative values of TA and TAC allow us to know the qualities of hydroxides and carbonates, or alkaline or alkaline earth bicarbonates in water. Alkalinity was measured using a titrated solution of sulfuric acid H_2SO_4 (Pasteur Institute of Algeria), in the presence of 50% phenolphthalein (Pasteur Institute of Algeria) (AT or simple alkalimetric titer) or methyl orange (Pasteur Institute of Algeria) (TAC or full alkalimetric titer).

Hardness (total hydrometric titer: THt)

The hardness of a water sample was measured directly by titration with 0.01 M solution of ethylenediamine tetraacetic acid (EDTA) (Pasteur Institute of Algeria) using eriochrome black T (EBT) (Pasteur Institute of Algeria) as an indicator.

Determination of nitrates and nitrites

The nitrate concentrations were determined by UV visible spectrophotometer. The concentration of the nitrate ion was proportional to the intensity of the coloring. The samples were processed in the range of 0-50 ppm and at a wavelength of 410 Nm.

For the nitrites determination a certain volume of Potassium permanganate ($KMnO_4$) (Pasteur Institute of Algeria) was added to the sample and analyzed in an acidic medium. Nitrite ions (NO^{2-}) only react with the permanganate ions. The solution was heated to complete the reaction. An excess amount of permanganate were measured by adding sodium oxalate which in turn is titrated with a standard solution of potassium permanganate.

Determination of heavy metals

The content of heavy metals (Iron, Lead, Copper, Cadmium and Nickel) was measured by atomic absorption spectrophotometry, after preparation of the samples by taking 100 mL of the sample and reducing the pH to 2.3 with an acidic solution.

Statistical analyses

The data collected was processed using SPSS version 22. The SPSS software was used to obtain the arrhythmic means and the standard deviations of each studied parameter.

Chi square test was applied to see association between physiochemical parameters and bacterial types. Data was transformed by applying test of normality, and independent sample T test was applied for physiochemical parameters of two sites (layer and broiler sites). The independent sample T test was also applied to notice significant difference in average concentrations of metals at *P* value (> 0.050 between two sites (layer and broiler sites).

Results

Epidemiological results

Out of a total of 15 poultry houses studied, 11 poultry farms buildings were located near towns, and the water supply was mainly from individual water sources.

For the broiler breeding, the cleaning of the drinking troughs was only carried out during the end of the breeding strip, when the breeding building was empty (the crawl space) and during the preparation for the establishment of a new breeding strip. It was also noticed the broiler chickens that raised in farms are of various breeds such as ISA, COBB500, Arbor-Acres aged 49-52 days at slaughter weighing 3-3.2 Kg on average, with a consumption index varying between 4.8kg up to 5.5kg/bird .While, for laying hen farms, drinking troughs were cleaned weekly for the majority of the poultry houses studied. The daily consumption varies between 100g/d up to 110g/d with an average production of 140-egg plates/d, during 22 months.

For turkey farms we have observed the application of hygiene measures to the strict minimum (absence of footbaths and rare cleaning of drinkers), the slaughter weight reaches an average weight of 20kg at ages varying from 4 months to 5 months.

The pathologies noted for all the species studied are mycoplasmosis, respiratory diseases, hemorrhagic enteritis and, coccidiosis.

Microbiological results

The microbial load of total coliforms (CT), faecal coliforms (CF) and faecal streptococci (SF) were expressed in CFU, referring to the Mac Grady MPN table.

The results of the average microbial load of bacteria analyzed has shown in Table 2, which showed higher levels of CT, followed by SF and CF.

Results of physico-chemical parameters and heavy metals analyses

The results of the physicochemical parameters and heavy metals were compared to the limit values described by the Official Journal of the Algerian Republic (JORA, 2011) and the World Health Organization (WHO) guidelines (WHO, 2017). These results showed high averages for hardness (69.30±71.93), alkalinity (53.35±61.17), chloride level (0.3501±0.43), iron (0.15±0.20) and cadmium (0.0056±0. 0119) (table 3).

Statistical results

A significant association was present between physiochemical parameters and bacterial types (CT, CF and SF) of two sites (layer and broiler sites) $P < 0, 05$.

For microbial analysis both the sites, non- significant results were noticed between microbes of two sites.

For physiochemical parameters, a non-significant difference was noticed between pH (p= 0.733), THT (p= 0.951), and NO_3 (p= 0.790). While, on the other hand, a significant difference was noticed for NO_2^- at p value 0.034 and in total alkalinity at p value 0.041, and Cl with P value 0.019.

No significant difference was present in average concentrations of metals $P > 0.05$ between two sites (layer and broiler sites).

Discussion

The examination of the values and the distribution of the physicochemical and bacteriological parameters of the drinking water of the poultry buildings of the region of Skikda gives us important information about the drinking water quality in the region.

In this study, we recorded various contaminations by total coliforms, fecal coliforms, and streptococci, which were 53%, 13% and 20% respectively. The analysis showed the absence of *Salmonella* in all the samples analysed. Above all, we noted that nine samples from five laying hen farms and four broiler farms showed high loads of total coliforms. Nevertheless, we noted low contamination in total and fecal coliforms in the P8 and P9. Our results corroborate with those of Eufrásia *et al*. (2022) who noted contamination of 40% for total coliforms and 15% for *E Coli*. Jafari *et al*. (2006), reported in their study of drinking water in broiler farms in Iran, that the number of microorganisms in the drinking water of birds should be 100 CFU/mL for total bacteria and 50 CFU/mL for coliforms (Jafari *et al*., 2006). Our results also corroborated those of Amaral *et al.*(2001), who reported, that samples from the water sources and reservoirs were contaminated by *E. Coli* in 10 broiler and laying hen farms evidencing fecal pollution of the samples (Amaral *et al*., 2001). Also Kassem Agha *et al.* (2022) reported that coliform counts and *E.coli* were respectively present in 91% and 50% of drinking water used in 35 broiler farms in Libya (Kassem Agha *et al*., 2022).

Fecal coliform was also detected in the majority of samples from drinking water from wells, indicating the occurrence of fecal contamination that could be due to free access of wild and domestic animals to the superficial water sources, disposal of animal excreta and dead carcasses, and even the drainage of human's sewage from the rural villages. Although the superficial water sources are more subjected to fecal contamination, the underground water is also susceptible to this type of pollution (Amaral, 2004). Surface water quality is subject to frequent, dramatic changes in microbial quality as a result of a variety of activities in a watershed. These changes are caused by the discharges of municipal raw waters or treated effluents at specified point source locations into receiving waters (river, lake) or by stormwater runoff into the drainage basin at nonpoint locations all over the watershed.

The birds are smaller and precocious animals, and their lower resistance may cause them to be more susceptible to infections, mainly caused by pathogens of intestinal origin that might be present in water with fecal pollution (Amaral, 2004). Drinking water plays an important role in the transmission of some bacterial, viral, and protozoan diseases that are among the most common poultry diseases. It is well known that conventional antimicrobials (antibiotics) have been used in livestock production, including poultry, as a preventive measure against or for the treatment of infectious bacterial diseases.

Interventions in poultry production can be assured by the administration of antibiotics in feed or drinking water. Food and Drug Administration (FDA) approved the use of antibiotics as animal additives without prescription, followed by European Union (EU) countries, which approved their own regulations on the use of those substances in animal production. Unfortunately, the use and misuse of these compounds has led to the development and dissemination of antimicrobial drug resistance, which is currently a serious public health concern (Abreu *et al.,* 2023).

Important factors to prevent waterborne diseases in broiler production are the protection of supply sources, water disinfection and the quality control of microbiological, chemical, and physical characteristics. Also, the use of organic acids as food additives created an acidic environment in the digestive tract system by lowering the pH in the intestinal tract, which prevented the development of pathogens and microorganisms (AL-Tamimy et al., 2022). Water is an essential component for birds and therefore quality preservation is fundamental for good flock performance. The farmer may prevent many diseases in bird flocks by controlling the quality of the ingested water, which will certainly result in decreased costs and increased profit, two essential aims of animal production nowadays. Many factors increase the risk of occurrence of waterborne diseases:

The inadequate disposal of organic and inorganic residues from agriculture and livestock productions. The privation of concern regarding the quality control of the drinking water given to animals, resulting in the low-quality availability of water to birds. There is a general belief that water sources in the rural areas have good quality and can be used as drinking water for both humans and animals, no matter if they have been submitted to adequate water treatment or not (Amaral, 2004).

All the results of the samples were of satisfactory quality in pH, nitrate, chlorides, copper, cadmium, and lead. However, we noted high rates for certain physicochemical parameters: hardness (69.30±71.93°F), alkalinity (53.3507±61.1743°F), nitrite (0.7076±1.1605 mg/L); and heavy metals such as iron (0.1568±0.2035 mg/L), cadmium (0.0056±0.0119 mg/L) and nickel (0.0256±0.0512 mg/L).

The pH of natural water depends on the underlying geological formation of the land. It can also be influenced by the oxygenation of the source, which affects pH (El Allaoui *et al*., 2016). Our results are corroborated with those of Khan *et al* (2013), who reported that the pH of drinking water equivalent to 7.5 resulted in the best performance and better economics. Moreover, low pH water is aggressive and can dissolve metal pipes releasing lead, copper and other minerals into the water (Watkins *et al*., 2004). Also, Veeramani *et al* (2003) reported better performance of broilers offered drinking water with acidic pH and poor performance on offering alkaline drinking water (Veeramani *et al*., 2003). According to the WHO recommendations, the source, raw water temperature, treatment and chemical or biological processes taking place in the distribution system influence the dissolved oxygen content of water. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulfate to sulfide. It can also cause an increase in the concentration of ferrous iron in the solution, with subsequent discoloration at the tap when the water is aerated (Who, 2017).

Water hardness is a measurement of the amount of salt in the water, primarily divalent ions like magnesium, calcium, and/or iron, which represents the total amount of divalent salts (Saleh *et al*., 2023). It was noted that out of a total of 15 samples, 11 samples showed values exceeding the safe limit (20°F) (73, 3%). These samples come from laying hen farm buildings (n=6), broiler farms (n=4), and a turkey farm whose water supply is mainly from wells. Our results corroborate with those reported by Eufrásia *et al.* (2022) in their study on the drinking water and original tap water of small-layer farmers in Southern Mozambique (Eufrásia *et al*., 2022). On the other hand, they noted a lower rate in borehole water (37, 5%) in the same study. Also Lekehal *et al*.(2016) noted an average of 55.2±27.8°F in their study conducted in the Batna region Algeria, with rates varying from 63°F to 78 °F (Lekehal *et al*., 2016). This high hardness interferes with the intestinal absorption of trace elements and macro elements, it promotes intestinal irritation, pecking, cannibalism and causes scaling of the watering equipment, that's why its high rate was considered evidence of heavy contamination and drew attention to the need for frequent cleaning and disinfection (El Allaoui *et al*., 2016; Saleh *et al*., 2023), Also hardness in drinking water can induce an unpleasant taste, reduced water consumption and decreased egg production in layer farming (Cardozo *et al*., 2015).

For alkalinity, the results of our study revealed that eight samples analyzed from six laying hen farms and two broiler farms; represent a content exceeding the standard recommended by the limit values of the Algerian official journal (J.O.R.A, 2011). Alkalinity is related to water hardness, these two parameters exceed the recommended standard, which reflects poor water quality, which could be a favourable environment for the development of bacteria.

Seven samples represent nitrite levels higher than the standard recommended by J.O.R.A (2011), our results are in contradiction with those reported by El Allaoui *et al*. (2016), who noted an average of 0.049 mg/L of nitrite in the analyzed water (El Allaoui *et al*., 2016).

Nitrite is a natural ion present everywhere in the environment. It is a product of nitrogen oxidation by microorganisms in plants, soil, or water (AFSSA, 2011). Traces of nitrites in water are often linked to pipes where corrosion is significant (AFSSA, 2001). The nitrate results revealed that all the concentrations of the samples analysed comply with the standards, this could be, because the study was carried out in spring, characterised by a mild climate, less rain and storms with drier soils. Several studies have shown that nitrate levels are high in winter and low in summer (AFSSA, 2011). Rainfall from agricultural soils, particularly in winter or following major storms shortly after fertilizer application, is a significant source of nitrates to surface waters. Sources of nitrate in groundwater and surface water include agrochemicals, surface runoff from irrigated lands, septic tanks, leakage from drainage networks, livestock wastes, manure storage, landfills, urban fertilizer use, industrial wastewater, sludge disposal etc. Over fertilisation leaves traces of nutrients in the soil even after harvesting (Brindha *et al*., 2017). The presence of nitrates in drinking water can alter the functions of thyroid hormones, which can harm the growth rate (Lekehal, 2016). Analysis of the water in the study area revealed normal amounts of chlorides ranging from 0.056mg/L in P6 and 0.63135mg/L in P1 and P3. It turns out according to certain studies that the consumption of the chicks decreases as the concentration of chloride is important in the water, which is regressed on the gain of the average weight (ADG) of the chicken and affects the productivity (Jiang *et al*., 2019). The dosage of trace elements was imperative in our study. Indeed, it should be noted that the major part of the trace elements (95 to 99 %), are ingested in quantities generally more than the needs of the animal, to accelerate growth and in the manufacture of foods such as margin of safety, can constitute a risk for the environment, mainly because of their phytotoxicity in the regions of intensive poultry production. It also highlights the importance of controlling the levels of trace elements in poultry feed to limit releases, particularly of heavy metals, into the environment.

The results concerning the levels of iron and copper in the water analysed, showed that most of the values of these parameters comply with the limit values, according to some authors, Dietary addition of Fe in the finisher phase improved meat quality, increased body weight of chicks and average daily feed intake in Ross ad Yellow broilers (Lin *et al*., 2020)

Also in broilers, copper intake above nutritional requirements (8 mg Cu/kg); may improve growth performance as an alternative to antibiotic growth promoters (National Research Council, 1994; Nguyen *et al*., 2022), however high levels of copper cause copper accumulates in the liver, and, consequently, contributes to the increased concentration of droppings, thereby leading to adverse effects on nutrient utilization (Yang *et al*., 2018). Copper in a drinking-water supply usually arises from the corrosive action of water leaching copper from copper pipes in buildings. High levels of dissolved oxygen have been shown to accelerate copper corrosion in some cases (WHO, 2017).

The accumulation of trace elements in our study can be explained by the phytotoxicity of soils and the toxicity of water wells, which are the main source of water for the majority of farms studied, however, the ultra-trace elements analysed in our study are cadmium, nickel and lead. For cadmium, two samples (P1and P2) show levels slightly exceeding the recommended standard, according to the INRA study, 2001, a cadmium deficiency slows the growth of chickens (I.N.R.A, 2001). By comparing our analysis results for nickel with the recommended standards, we notice a high rate for the P12 sample. An excess of nickel leads to poor growth and anemia (I.N.R.A, 2001). Water pollution is an undesirable change in water's physical and chemical properties, numerous factors, including hardness, pH, and total dissolved solids, affect water consumption in chicken farms. Minerals and salts at high concentrations in animal drinking water produce physiological abnormalities in broilers, resulting in loss of the broilers' health, growth, feed intake, and immune status (Saleh *et al*., 2023). Due to the negative effect of chemical residues on the nutritional value of bird carcasses, medicinal plants are used to improve the quality and growth of this industry (Abdulameer et al., 2022; Merzah et al., 2022).

Conclusions

From this study, it seems to appear that the quality of the water analyzed is far from satisfactory and showed various contaminations by coliforms, streptococci, and certain physico-chemical parameters and heavy metals. The quality of drinking water in poultry farms has a considerable influence on the success of a farm and its profitability. The results of the physico-chemical analysis of the water showed that pH, nitrates, chloride, and some heavy metals such as copper and lead can be considered below the permissible levels and were safe for consumption in poultry. However, the problem lies in the levels of total hardness and alkalinity, nitrites, iron, cadmium and nickel which were above the standards. These results may have an impact on the solubility of antibiotics used as vaccines for poultry. Water contamination can have an impact on the health of poultry through certain respiratory or digestive diseases. The causes of this pollution are multiple; among which we can cite the poor protection of wells, the poor design of septic tanks, and the presence of sources of pollution, such as deposits of poultry manure near the wells. In light of this study, it was recommended to improve the quality of water in poultry farming, to advise the breeder to protect the wells against contamination and to install drinking water purification stations. In addition, the cleaning and disinfection of poultry buildings and silos at the end of each band must be carried out rigorously to prevent the passage of pathogens between two successive bands. Finally, to correct the non-compliant physico-chemical parameters, the breeder can acidify the water (pH correction), cover it with softeners (correction of the hardness), and carry out denitrification (correction of the presence of nitrites and nitrates).

Conflict of interest

The authors declared no conflict of interest.

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Table 1. Origin and nature of samples studied

N° of samples	Origin of samples	Type of farm
P1	water well	laying chicken

P2	water well	laying chicken
P3	water well	laying chicken
P4	water well	broiler chicken
P5	water well	laying chicken
P6	water well	broiler chicken
P7	water well	laying chicken
P8	public water network	broiler chicken
P9	public water network	Turkey
P10	water well	laying chicken
P11	water well	laying chicken
P12	water well	broiler chicken
P13	water well	broiler chicken
P14	water source	broiler chicken
P15	water well	broiler chicken

Table 2. Mean bacterial count (CFU mL^{-1}) water samples

Bacterium	**Mean ± standard deviation**
CT	167,9±379
CF	17,13±54,48
SF	131,1±296,56
Salmonella	0

CT: Total coliforms (UFC/mL), CF: Faecal coliforms (UFC/mL), SF: Faecal streptococci (UFC/mL)

Table 3. Mean and standards of the physico-chemical analysis of the drinking water of the poultry farm buildings studied

Settings	Mean ± standard deviation	limit values
pH	7,07±0,44	≥ 6,5et ≤9
THT	69,30±71,93	20
TAC	53,35±0,39	50
NO2	0,70±1,16	0,2
NO3	2,61±4,28	50
Cl	0,35±0,35	500
Fe	0,156±0,203	0,3
Cu	0,059±0,110	2
Cd	0,0056±0,0119	0,003
Ni	0,02±0,05	0,07
Pb	0	0

THT: Hardness (°F); TAC; Alkalinity (°F); NO_2^-: Nitrites (mg/L); NO3: Nitrate (mg/L); Cl: Chloride (mg/L); Fe: Iron (mg/L); Cu; Copper (mg/L); Cd: Cadmium (mg/L); Ni: Nickel (mg/L); Pb: Lead