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Assessment of Groundwater Quality and Its Impact on Poultry Farming in Haryana, India

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ABSTRACT

The quality of the water used for daily operations has a significant impact on the sustainability and profitability of chicken farming. This research evaluates the physicochemical, microbiological and heavy metal quality of groundwater from 100 chicken farms spread throughout several regions of Haryana, India. The following parameters were analysed in accordance with standard BIS and WHO guidelines: pH, total dissolved solids (TDS), total hardness, calcium carbonate, nitrate, nitrite, chloride, fluoride, sulphate, coliform count, total viable count (TVC) and lead contamination. The results indicated that a significant portion of the water samples contained levels of TDS, hardness, nitrates, sulphates, fluoride, coliforms and lead that were over permissible limits, with detrimental effects on public health, productivity and poultry health. More over two-thirds of the samples included coliforms, indicating a very high level of microbial contamination. According to the research, there is a strong correlation between poor water quality and poor chicken performance indicators including mortality, weight increase and feed conversion ratio. The study finds that in order to support sustainable chicken production and safeguard public health in Haryana, effective treatment methods, ongoing water quality monitoring and well-informed policy interventions are absolutely necessary.

Keywords

Groundwater quality, poultry farming, Haryana, total dissolved solids, microbial contamination, heavy metals, waterborne diseases, coliforms, feed efficiency, public health, water treatment, sustainability.

Introduction

Water is a basic molecule that constitutes the foundation of terrestrial life. With two hydrogen atoms and a single oxygen atom, water (H_2O) not only plays a vital role in chemical reactions but also serves as a transport medium for nutrients, temperature control and biological stability across all living organisms. In living organisms, water normally makes up 60–90% of body weight, varying with the organism and its physiological status (Nesheim et al., 1979). Without water, essential functions such as digestion, circulation, excretion and cellular metabolism would all stop functioning.

Availability of Water

Even though planet Earth is referred to as the "blue planet," it contains only a meager 2.5% of freshwater and less than 1% of this is readily available for direct use by humans and animals because the remaining amount is locked up in glaciers or deep aquifers (FAO, 2020). This scarce resource is under mounting pressure from population growth, industrialization and expansion of agriculture.

Usage of Groundwater

Groundwater comprises more than 30% of the freshwater on Earth and is an important source of water for drinking, irrigation and livestock. In India, around 85% of rural drinking water and 60% of irrigation water rely on groundwater (Central Ground Water Board, 2022). Despite its importance, overexploitation and pollution due to anthropogenic activities have resulted in the degradation of quality and reduction in quantity. In Haryana, for example, almost 55% of groundwater is not suitable for agriculture or livestock because it is salinated and contains other pollutants (Manchanda et al., 1989; Vohra, 1980).

Water Dependency of Living Organisms

Water is absolutely necessary to all living organisms' plants use it for photosynthesis and nutrient acquisition and animals require it for hydration, thermoregulation and metabolic processes. Birds, more than any other group, are very much reliant on water because of their high metabolism and inability to sweat. Broilers, for example, obtain 55–75% of their body weight from water and may drink twice their weight in water every time they eat feed (Blake & Hess, 2001). In hot stress conditions, it can increase to four times the feed.

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Birds and Water Requirements

In bird species, water plays more than one physiological function digestion, regulation of body heat, delivery of nutrients and elimination of waste. In poultry production, particularly broiler rearing, the amount and quality of water play an important role in growth performance, immunity and mortality (Koelkebeck, 2012). Unclean water might bring about pathogens and toxic substances into the flock, which may lead to disease, lowered feed utilization and economic loss (Do Amaral, 2004).

Connecting with Poultry Farming in Haryana

Haryana is one of India's most intensive poultry-producing states, with Jind, Panipat, Hisar, Karnal, Sirsa and Fatehabad districts becoming major hubs (Department of Animal Husbandry & Dairying, Haryana). The industry has experienced substantial growth with rising protein demand and the evolving application of technology. However, growth relies extensively on groundwater, which in the region is frequently of poor quality. Research has shown elevated levels of total dissolved solids (TDS), nitrate, fluoride and coliform bacteria, as well as lead contamination in poultry farm water sources (Aziz et al., 2017; Al-Saffawi et al., 2020). Since the present study reveals, more than two-thirds of the poultry farms examined in Haryana contained microbiologically unsafe water with coliforms and high TVC levels (present study). Physiological stress resulting from the intake of such water adversely influences bird weight gain, feed conversion ratio (FCR) and flock health. The value of safe and clean water cannot be emphasized enough not only in maintaining poultry health but also in protecting public health and poultry industry economic sustainability. This study seeks to empirically assess the physicochemical and microbial quality of groundwater used in Haryana's poultry farms and its effect on poultry productivity indicators.

The poultry sector, over the last few decades, has seen an unprecedented rate of growth, fueled by shifting eating habits, rising protein demand and progress in breeding and production technologies. Whereas the overall agricultural industry has been increasing at a 1.5% to 2% average annual growth, the poultry industry has been growing invariably by 8% to 10% per annum (Kumutha & Karthikeyan, 2020). The high growth of poultry farming has largely contributed to rural employment generation, economic progress and nutrition security in the country. As per the 20th Livestock Census (2019), India's total poultry population increased to 851.81 million from 729.21 million in 2012, an enormous growth of 16.81%. India's broiler meat production has also registered significant growth, from 6.69 million tons during 2014–15 to 9.29 million tons during 2021–22, registering a growth rate of 5.62%. These figures make India the third-largest egg producer and eighth-largest producer of broiler meat in the world (PIB, 2022). One such state in northern India is Haryana, which has been the prime mover behind this growth. Jind, Panipat, Hisar, Karnal, Sirsa and Fatehabad districts are some of the key broiler production hubs (Department of Animal Husbandry & Dairying, Haryana).

Water is the most essential nutrient in poultry and performs a central role in all the physiological functions such as digestion, nutrient uptake, waste removal, temperature regulation and metabolic processes. Water is estimated to make up 55% to 75% of a chicken's body weight (Nesheim et al., 1979). Chickens normally drink close to double the amount of water as feed by weight and during heat stress conditions, water intake can be as high as four times under normal (Blake & Hess, 2001). Although it is globally accepted as the most critical nutrient, it is hard to define the precise water requirement for poultry because it varies as a function of temperature, age, feed types and health. The purity of the water fed to poultry has a direct and substantial effect on their health and performance. Impure or poor-quality water can introduce heavy metals, chemical toxins and pathogens into the bird's body, causing disease outbreaks, stunted growth, low feed efficiency and increased mortality. Waterborne diseases can spread quickly among a flock, while feces, infected bird secretions and contaminated water through humans or other animals can be sources of infestation (Do Amaral, 2004). Excessive total dissolved solids (TDS), salinity, or microbial burden can disrupt physiological equilibrium, inhibit nutrient absorption and weaken the immune system of poultry. Vohra (1980) reported that groundwater in Haryana’s semi-arid regions is typically brackish, exhibiting Total Dissolved Solids (TDS) concentrations ranging from 1,000 to 10,000 mg/L. This deteriorating water quality, marked by high salinity, hardness and the presence of nitrate, sulfate, fluoride and even heavy metals, poses serious challenges for poultry farming in the state. Given Haryana’s heavy reliance on groundwater for agricultural and livestock purposes, such contamination significantly threatens both bird health and feed stability. Manchanda et al. (1989) have indicated that 55% of Haryana's groundwater is poor in quality and will possibly not be acceptable for use in livestock or agriculture. This will be a serious problem for poultry farmers who do not use any water other than borewell or tube well water.

Different physicochemical and biological parameters are routinely employed to evaluate groundwater quality. These are pH, electrical conductivity (EC), total hardness, calcium, magnesium, nitrate, nitrite, sulfate, fluoride, chloride and TDS. Microbial impurities like coliforms and total viable bacteria are also important indicators of sanitary quality. Acceptable and unacceptable levels of these parameters have been established, not just for human use but also for use by animals (Koelkebeck, 2012). For example, an excess of nitrates can cause toxicosis, while high sulfate levels are associated with diarrhea and poultry mortality (Tyagi et al., 2006). Excessive levels of chloride above 50 ppm can harm water palatability and consumption, especially in low temperatures (Damron & Flunker, 1993). A study by El-Badry et al. (2015) established that drinking water with high salt content (sodium, potassium and chloride) was linked with broiler poor performance. The heavy metals such as lead and arsenic can accumulate in the bird tissues with the possibility of entering the human food chain and causing health hazard to consumers. The pathogens like Escherichia coli, Salmonella and Shigella, which are predominant in contaminated water, have the ability to trigger enteric diseases in poultry and zoonotic diseases in humans (Mohammed et al., 2020).

Empirical research based on Indian and global contexts has revealed that there exists a strong relationship between poultry health and water quality. Aziz et al. (2017) tested the effect of brackish water on broiler chickens in Haryana and found that high bicarbonate, chloride and calcium content in water caused higher mortality and poorer carcass quality. Boumedous et al. (2017) established that poultry farm drinking water did not meet World Health Organization (WHO) standards and thus compromised bird performance. Similarly, Al-Saffawi et al. (2020) reported that 36% of groundwater samples in Iraq's Mosul region were unfit for poultry use due to high bacterial loads. In a different study, Cao et al. (2021) evaluated the impact of livestock farm wastewater on adjacent groundwater and surface water in Vietnam. Their results demonstrated that poultry farm effluents considerably elevated the level of coliform bacteria, making more than 70% of groundwater samples unfit for consumption. Augusto et al. (2022), examining small poultry farms in Mozambique, identified water quality as suboptimal owing to high total hardness and bacterial contamination.

Kumutha and Karthikeyan (2020) highlighted that poor disposal practices of poultry manure and the release of untreated sewage from farms significantly contribute to environmental pollution in Haryana. These local environmental behaviors intensify groundwater

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contamination, particularly in low-lying regions or areas with high water tables, where the percolation of contaminants into aquifers is more pronounced. The threat is further compounded by inadequate regulation of poultry waste management and the absence of systematic monitoring of water sources, exacerbating the existing groundwater quality crisis in the region. With the importance of the quality of water in deciding the success of poultry farms and the public health impact that can be potentially caused, there is an urgent need for precise regional research that evaluates the groundwater quality and relates it with the productivity indices of poultry. Even though generalized guidelines regarding water quality are available, there is limited focused research that associates precise water quality parameters with broiler health and performance indicators in Haryana. The current research fills this vital lacuna by conducting a detailed evaluation of poultry farm groundwater quality in different districts of Haryana. The study includes an evaluation of physicochemical and microbial parameters of water samples from 100 poultry farms. The study further assesses the occurrence of heavy metals, with a focus on lead, in order to appreciate the possible toxicological hazards. By comparing these results to important performance measures like feed conversion rate, weight growth, death rate and health condition, the research seeks empirical evidence on how groundwater quality impacts poultry farming results. This study is important not just for enhancing the health and productivity of poultry but also for maintaining food safety and public health. Contaminated water use in poultry production may result in the retention of toxic compounds in meat and eggs, hence risking the health of consumers. In addition, the same water sources are shared by farm workers and their households for domestic and drinking purposes, making it easier to transmit zoonotic diseases. Through the development of water quality standards specific for poultry production in Haryana, the study results will assist policymakers, veterinarians and farmers in the establishment of efficient water treatment and management strategies. These strategies will not only increase the sustainability of poultry production but also support environmental protection and rural health enhancement. Through this, the study enhances the universal objectives of agricultural sustainability, food security and public health protection.

METHODOLOGY

The research was carried out on 100 poultry farms in various districts of Haryana. Aseptic collection of groundwater samples was done in sterilized glass bottles of 1-liter capacity after five minutes of running water to provide a representative sample. The samples were kept in

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refrigerated boxes and transported to the laboratory for further studies. The physico-chemical parameters analyzed were pH (measured with the help of a calibrated pH meter), total dissolved solids (TDS) by TDS meter and total hardness by the titrimetric procedure. Calcium carbonate was titrated with EDTA, while nitrite and nitrate content was estimated using manual colorimetry (HiMedia test kit). Chloride was determined by silver nitrate titration with potassium chromate as the indicator.

Fluoride content was determined with the help of a visual color comparison method (Merck Fluoride Test Kit). Sulphate content was determined employing spectrophotometry at 420 nm (Merck Sulphate Test Kit). Heavy metal contamination, especially lead, was ascertained through 15% potassium iodide solution as an indicator. Microbiological analysis consisted of coliform enumeration, which was estimated by Most Probable Number (MPN) test using a three-set test tube method (HiMedia MPN Kit). Total viable count per ml was done by pour plate method on plate count agar with incubation at 37°C and 22°C for various sets. All the procedures followed standard operating procedures and BIS/WHO guidelines to maintain comparability and consistency. The results were analyzed statistically to relate groundwater quality with indicators of poultry performance like weight gain, mortality and feed efficiency.

RESULTS

Water quality in poultry farming has a crucial role in defining the health and productivity of birds. Poultry birds, particularly broilers, are highly sensitive to changes in the environment and among the various factors affecting them, water is one of the key factors that regulate metabolism, thermoregulation, digestion of feed and immunity. A sample of 100 water samples from poultry farms in the state of Haryana, which is widely recognized for its contribution to India's broiler production industry, was taken in this research. The physico-chemical, microbiological and heavy metal properties of the water were determined by standardized analytical procedures. All the parameters were interpreted in the context of acceptable norms specified by the World Health Organization (WHO) and the Bureau of Indian Standards (BIS) for drinking water quality. The implications of all the parameters were assessed not merely in relation to poultry health but human health, since the common water sources are utilized for the birds and farmers as well. This article provides a parameter-wise intensive analysis of the findings, beginning with simple measures such as pH, TDS and total hardness, moving towards microbial contamination and the presence of heavy metals. The findings will identify standards

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deviations, possible health hazards and the necessity of constant water quality monitoring in poultry farms. This will assist in formulating region-specific water usage guidelines for poultry farming to provide safe, profitable and sustainable poultry farming in Haryana.

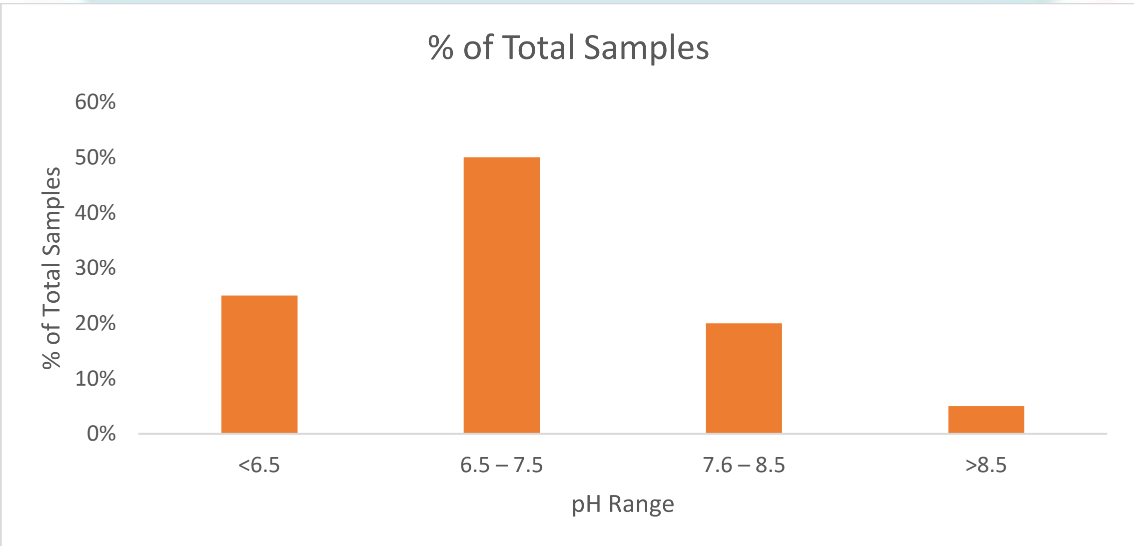
1. **pH of Water Samples**

Among 100 water samples tested, 50% of the samples were in the optimum pH range of 6.5–7.5, which is acceptable and compliant according to WHO/BIS. Twenty percent of the samples had slightly alkaline pH (7.6–8.5), which is acceptable. But 25% of samples were slightly acidic (<6.5) and 5% were alkaline (>8.5), both outside the acceptable range of 6.5–8.5 and not acceptable. The mean pH was 7.45 with range 6.1–8.8 and ±0.56 standard deviation. Although the majority of samples are compliant in terms of quality, a considerable minority suggest potential water quality issues.

Table 1: Statistical Analysis of pH in Water Samples (n = 100)

pH Range	No. of Samples	% of Total	Mean pH (Range)	Standard Deviation	WHO/BIS Standard	Status
<6.5	25	25%	6.1 – 6.4	±0.12	6.5 – 8.5	Slightly acidic – Not acceptable
6.5 – 7.5	50	50%	6.6 – 7.5	±0.22	6.5 – 8.5	Ideal – Acceptable
7.6 – 8.5	20	20%	7.6 – 8.5	±0.21	6.5 – 8.5	Acceptable
>8.5	5	5%	8.6 – 8.8	±0.09	6.5 – 8.5	Alkaline – Not acceptable

FIGURE 1: PH IN WATER SAMPLES



Source: Table 1

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2. Total Dissolved Solids (TDS)

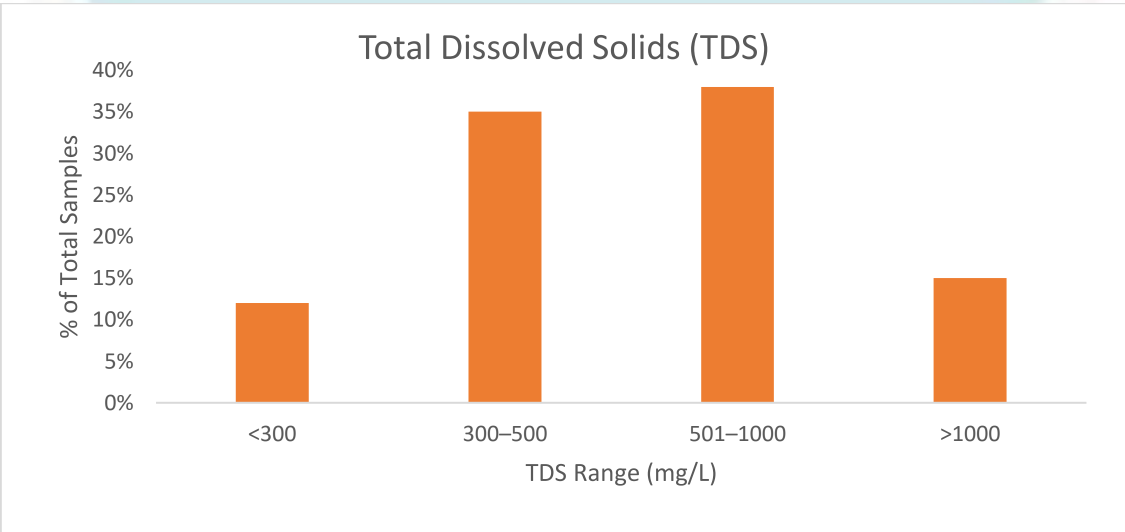
Total Dissolved Solids (TDS) indicate the amount of dissolved inorganic salts and minute traces of organic matter present in water. High TDS would change the taste, palatability and physiological equilibrium of poultry, its growth performance and health status. Water with a TDS level less than 500 mg/L is rated as very good for poultry consumption, whereas levels of more than 1000 mg/L are rated brackish and could induce negative effects.

In the current research, 100 poultry farm water samples were determined for TDS on a calibrated TDS meter. The samples showed large variability due to local hydro-geological conditions, irrigation runoff and waste disposal practices.

Table 2: Statistical Analysis of Total Dissolved Solids (TDS) in Water Samples (n = 100)

TDS Range (mg/L)	No. of Samples	% of Total	Mean TDS (mg/L)	Std. Deviation	WHO/BIS Standard	Status
<300	12	12%	226.5	±58.5	<500	Excellent – Highly suitable
300–500	35	35%	418.6	±61.3	<500	Good – Suitable
501–1000	38	38%	731.4	±75.2	Max 1000	Fair – Marginally suitable
>1000	15	15%	1294.3	±142.7	Not acceptable	Brackish – Unsuitable for poultry

Figure 2: Total Dissolved Solids (TDS) in Water Samples



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3. Total Hardness

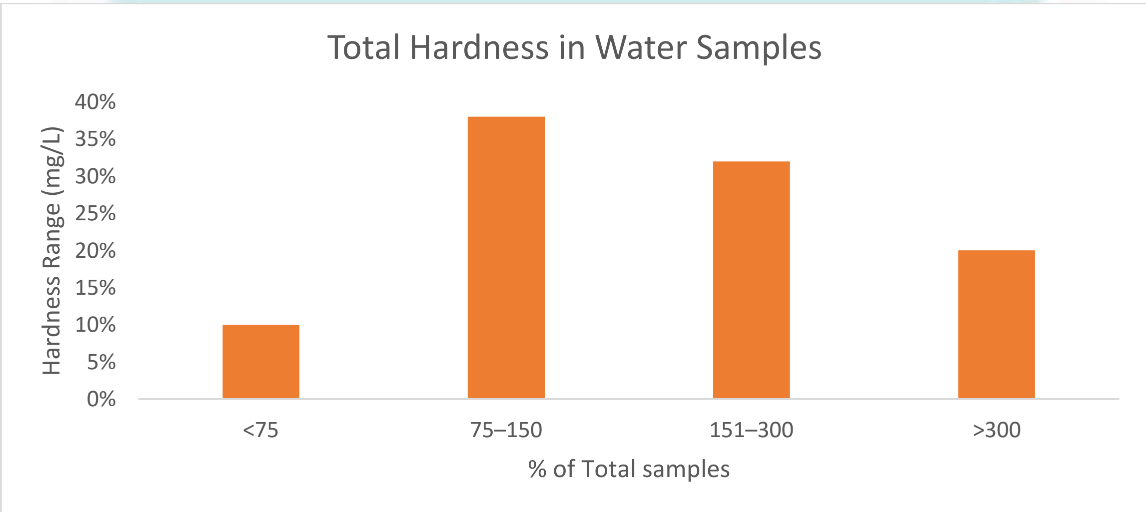
Total hardness in water is primarily caused by the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. While moderate hardness is not harmful and even supplies essential minerals, excessive hardness can lead to scale formation, reduced palatability and digestive problems in poultry. It may also interact negatively with certain medications and disinfectants used in poultry farms.

For poultry, water hardness up to 75–150 mg/L is considered acceptable. Values above 300 mg/L are often reported to cause reduced water intake and stress in birds. The hardness of the 100 water samples was determined using the titrimetric EDTA method.

Table 3: Statistical Analysis of Total Hardness in Water Samples (as $CaCO_3$) (n = 100)

Hardness Range (mg/L)	No. of Samples	% of Total	Mean Hardness (mg/L)	Std. Deviation	WHO/BIS Standard	Status
<75	10	10%	64.5	±6.4	75 – 150	Soft – Acceptable
75–150	38	38%	116.3	±21.2	75 – 150	Moderately hard – Suitable
151–300	32	32%	218.6	±36.5	Max 300	Hard – Marginally suitable
>300	20	20%	376.8	±52.1	Not recommended	Very hard – Not suitable for poultry

Figure 3: Total Hardness in Water Samples



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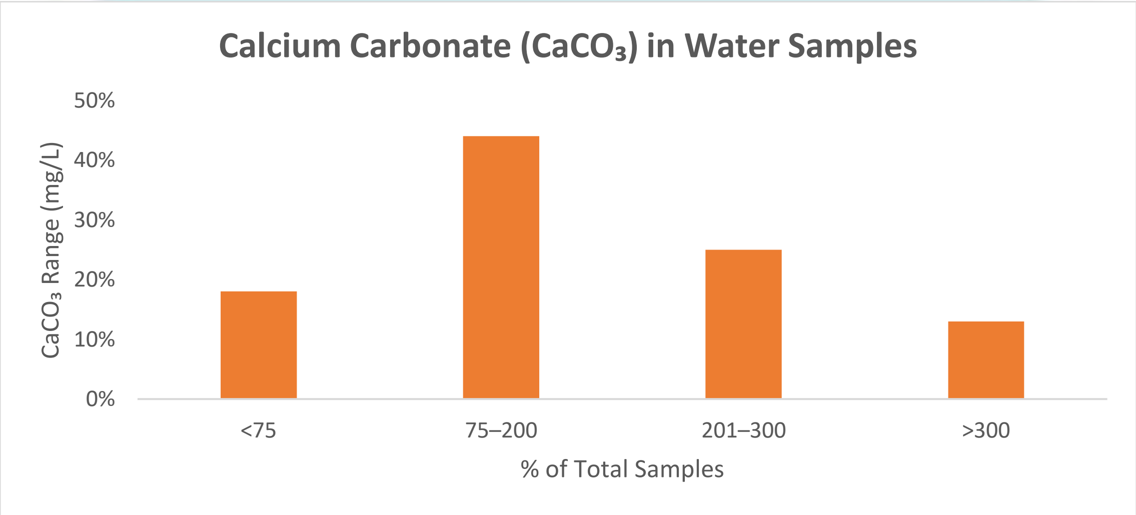
4. Calcium Carbonate ($CaCO_3$)

Calcium carbonate is one of the key contributors to water hardness and directly affects the digestive efficiency, shell quality and bone strength in poultry. While calcium is an essential mineral for poultry, especially laying hens and growing broilers, an excess concentration can interfere with the absorption of other critical nutrients like phosphorus and magnesium. In this study, the calcium carbonate concentration in water was estimated via titrimetric analysis using EDTA solution and the results were expressed in mg/L. The desirable limit for calcium as per WHO/BIS guidelines is 75–200 mg/L, beyond which it may cause physiological stress and gastrointestinal issues in birds.

Table 4: Statistical Analysis of Calcium Carbonate ($CaCO_3$) in Water Samples (n = 100)

$CaCO_3$ Range (mg/L)	No. of Samples	% of Total	Mean $CaCO_3$ (mg/L)	Std. Deviation	WHO/BIS Standard	Status
<75	18	18%	62.4	±8.2	75 – 200	Low – Borderline deficiency risk
75–200	44	44%	142.5	±31.7	75 – 200	Optimal – Suitable
201–300	25	25%	246.8	±29.2	Max 200	High – May cause absorption issues
>300	13	13%	378.6	±46.5	Not recommended	Very high – Not suitable for poultry

Figure 4: Calcium Carbonate ($CaCO_3$) in Water Samples



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5. Nitrate and Nitrite Levels in Water Samples

Nitrate (NO_3^-) and nitrite (NO_2^-) are nitrogen-based compounds commonly found in agricultural runoff, decomposing organic matter and sewage contamination. While nitrate is relatively less toxic, nitrite is more reactive and harmful. Elevated levels can cause methemoglobinemia in young birds, reduced egg production, poor growth and even death in extreme cases. As per WHO guidelines, acceptable limits are:

- **Nitrate**: <50 mg/L
- **Nitrite**: <3 mg/L

Table 5: Statistical Summary of Nitrate and Nitrite Content in Water Samples (n = 100)

Compound	Range (mg/L)	No. of Samples	% of Total	Mean Value (mg/L)	Std. Deviation	WHO Standard	Status
Nitrate	<50	73	73%	32.1	±9.4	<50 mg/L	Safe – Within limit
	>50	27	27%	74.3	±11.6	Not acceptable	Unsafe – Risk of nitrate toxicity
Nitrite	<3	88	88%	1.7	±0.6	<3 mg/L	Safe – Within limit
	>3	12	12%	4.8	±0.9	Not acceptable	Unsafe – May cause toxicity in poultry

6. Chloride Content

Chloride ions are naturally present in groundwater and are essential in small amounts for maintaining electrolyte balance and osmotic pressure in poultry. However, elevated chloride levels can contribute to salinity, poor water palatability and in combination with sodium, can induce salt toxicity in birds. The acceptable chloride level for poultry drinking water is typically below 250 mg/L. High concentrations can cause diarrhea, renal dysfunction and reduced feed and water intake, particularly in broiler birds which are sensitive to electrolyte imbalances. In this study, chloride concentration was determined by titrimetric method using silver nitrate and

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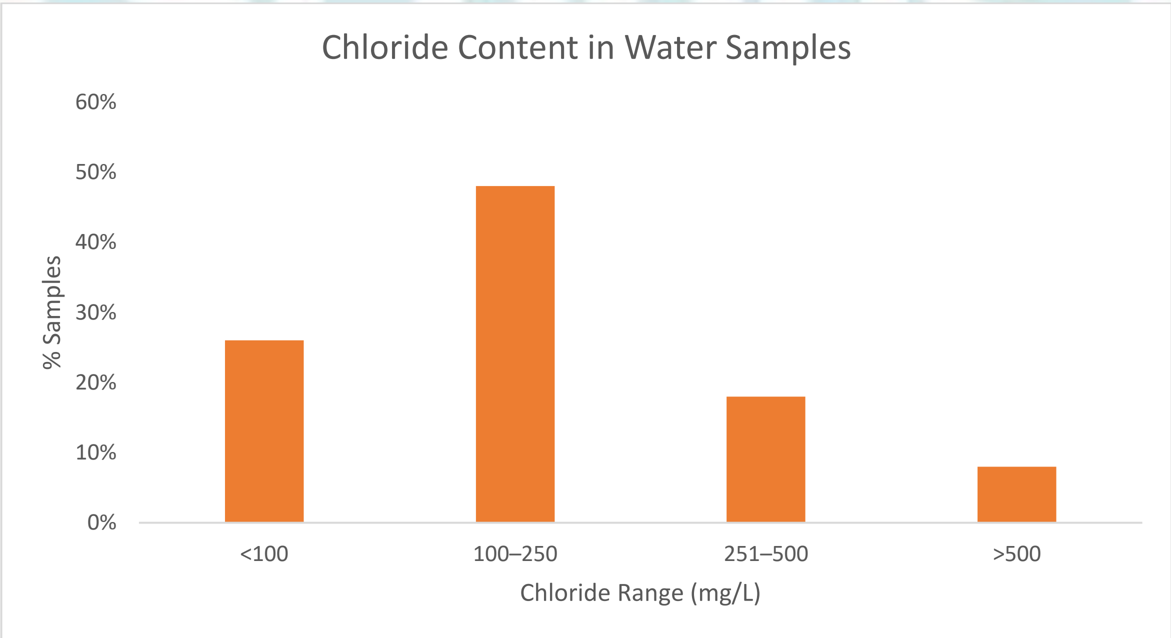
potassium chromate as an indicator. The variation in chloride levels reflects both natural sources and anthropogenic influences such as agricultural runoff or poor waste disposal.

Table 6: Statistical Analysis of Chloride Content in Water Samples (n = 100)

Chloride Range (mg/L)	No. of Samples	% of Total	Mean Cl^- (mg/L)	Std. Deviation	WHO/BIS Standard	Status
<100	26	26%	84.2	±11.6	<250	Excellent – Safe for poultry
100–250	48	48%	179.6	±38.2	<250	Acceptable – No expected issues
251–500	18	18%	334.7	±53.6	Max 250	High – May impair poultry performance
>500	8	8%	612.4	±67.4	Not acceptable	Very high – Risk of salt toxicity

Figure 5: Chloride Content in Water Samples



Source: Table 6

7. Fluoride Content in Water Samples

Fluoride (F^-) is naturally found in groundwater and originates from the dissolution of fluoride-containing minerals. While low concentrations (up to 1.0 mg/L) can be beneficial for dental

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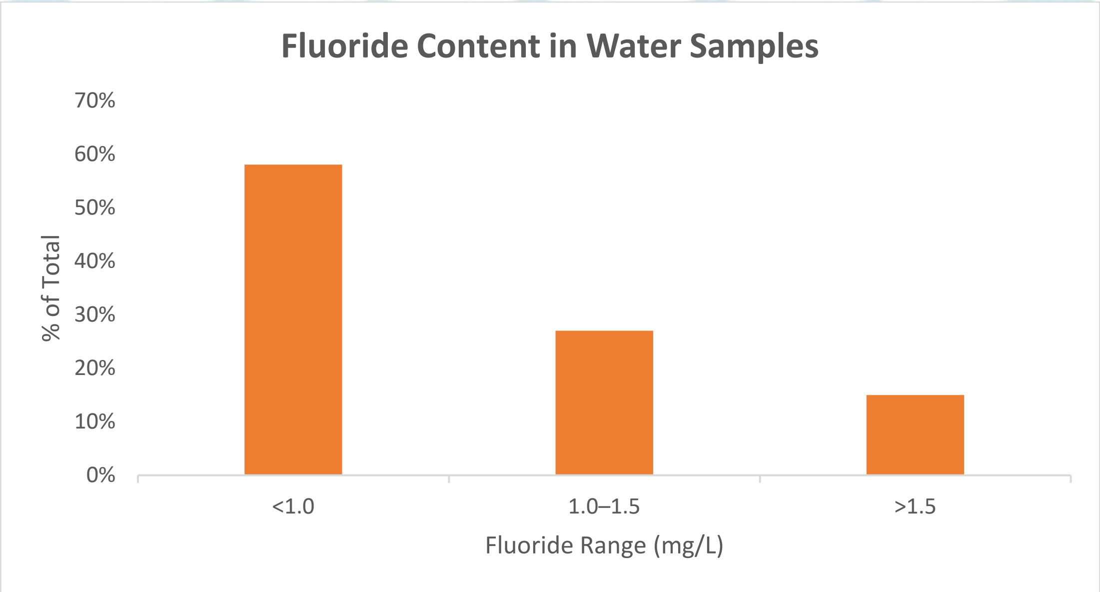
health in humans, excess fluoride can lead to fluorosis, skeletal deformities and enzyme inhibition. In poultry, chronic exposure to high fluoride levels may cause bone fragility, decreased feed efficiency and egg production disorders. The WHO guideline for fluoride in drinking water is ≤1.5 mg/L.

Table 7: Statistical Summary of Fluoride Content in Water Samples (n = 100)

Fluoride Range (mg/L)	No. of Samples	% of Total	Mean Fluoride (mg/L)	Std. Deviation	WHO Standard	Status
<1.0	58	58%	0.63	±0.18	≤1.5 mg/L	Safe – No toxicity risk
1.0–1.5	27	27%	1.26	±0.12	Within limit	Acceptable – Close to upper threshold
>1.5	15	15%	2.07	±0.31	Exceeds WHO	Not acceptable – May affect poultry metabolism

Figure 6: Fluoride Content in Water Samples



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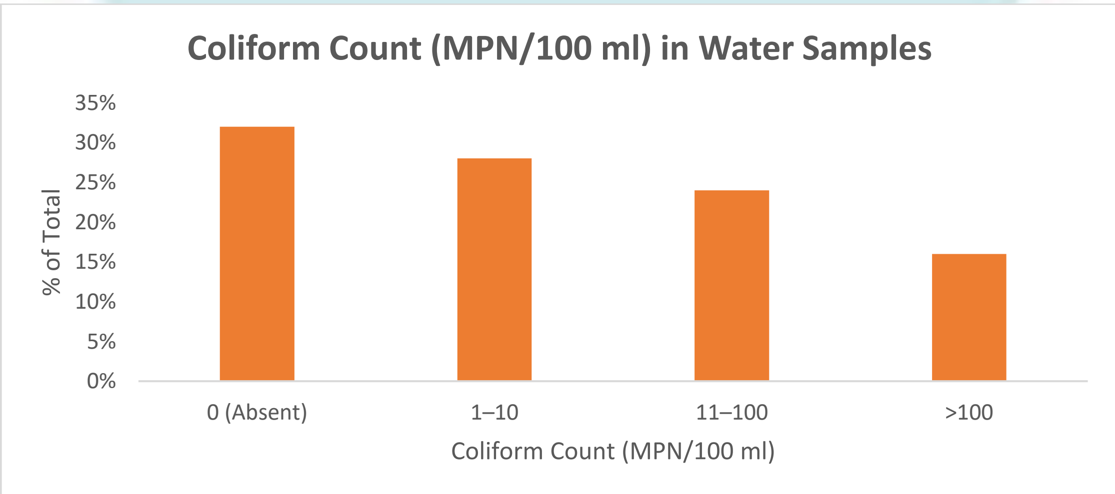
8. Coliform Count

Coliforms are a group of bacteria commonly used as indicator organisms to assess the sanitary quality of drinking water. Their presence indicates potential contamination from fecal matter and the risk of pathogens like Salmonella, E. coli and Shigella. In poultry farming, contaminated water can act as a vector for disease transmission, leading to enteric infections, reduced growth rates, poor feed conversion and increased mortality. Coliform levels are particularly important in closed broiler systems, where infection can spread rapidly. Water samples were analyzed for coliform count using the Most Probable Number (MPN) method with a 3-set tube series for statistical estimation of bacterial load per 100 ml. WHO recommends zero coliforms per 100 ml for drinking water. Any presence is considered unsafe.

Table 8: Statistical Summary of Coliform Count (MPN/100 ml) in Water Samples (n = 100)

Coliform Count (MPN/100 ml)	No. of Samples	% of Total	Status	WHO Standard
0 (Absent)	32	32%	Excellent – Safe for poultry	0/100 ml – Acceptable
1–10	28	28%	Slight contamination – Risk present	Not acceptable
11–100	24	24%	Moderate contamination – Unsafe	Not acceptable
>100	16	16%	Heavy contamination – Highly unsafe	Not acceptable

Figure 7: Coliform Count (MPN/100 ml) in Water Samples



Source: Table 8

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9. Total Viable Count (TVC)

Total Viable Count (TVC), also referred to as Standard Plate Count (SPC), estimates the number of aerobic heterotrophic bacteria present in a water sample. A high TVC indicates general microbial contamination, which may or may not be pathogenic, but still poses a significant threat in poultry farms due to its impact on bird immunity, water palatability and hygiene standards.

In this study, TVC was assessed using the pour plate method after performing serial dilutions. The samples were incubated at 37°C for mesophilic organisms and 20–22°C for psychrotrophic organisms. WHO recommends TVC levels to be <100 CFU/ml for safe drinking water. Higher counts suggest biofilm formation, stagnant water and hygiene failure.

Table 9: Statistical Summary of Total Viable Count (CFU/ml) in Water Samples (n = 100)

TVC Range (CFU/ml)	No. of Samples	% of Total	Mean TVC (CFU/ml)	Std. Deviation	WHO Standard	Status
<100	29	29%	62.4	±21.5	<100 CFU/ml	Safe – Acceptable for poultry
100–500	35	35%	318.7	±81.6	Not acceptable	Moderate load – May impair gut health
501–1000	21	21%	726.2	±108.3	Not acceptable	High load – Potential health threat
>1000	15	15%	1435.5	±172.6	Not acceptable	Very high – Unsafe, requires treatment

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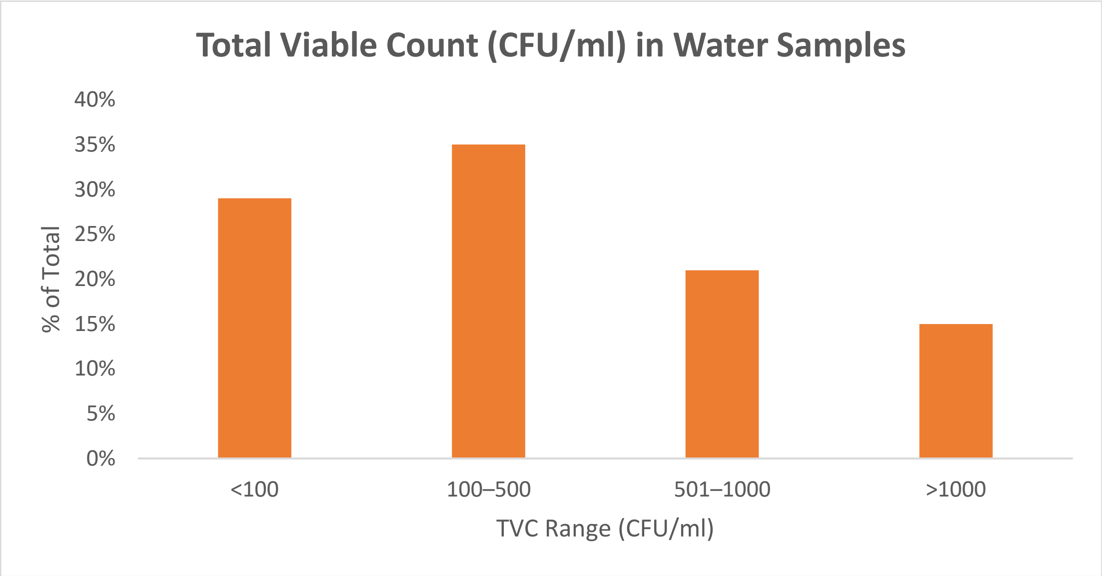
Figure 8: Total Viable Count (CFU/ml) in Water Samples



Source: Table 9

Sulphate Content in Water Samples

Sulphate is a naturally occurring anion in water, often originating from soil and rock formations, agricultural runoff, or industrial effluents. While moderate levels of sulphate are generally not harmful, high concentrations can lead to poor water palatability, diarrhoea in poultry and reduced productivity. According to WHO and BIS guidelines, sulphate levels should not exceed 250 mg/L for safe consumption.

Table 10: Statistical Summary of Sulphate Content in Water Samples (n = 100)

Sulphate Range (mg/L)	No. of Samples	% of Total	Mean Sulphate (mg/L)	Std. Deviation	WHO Standard	Status
<100	33	33%	72.5	±18.3	<250 mg/L	Safe – No impact on poultry
100–250	38	38%	185.4	±36.1	<250 mg/L	Acceptable – Within permissible range
251–500	21	21%	328.7	±42.9	Not acceptable	May impair digestion, risk of diarrhoea
>500	8	8%	622.9	±63.5	Not acceptable	High risk – Unsafe, needs treatment

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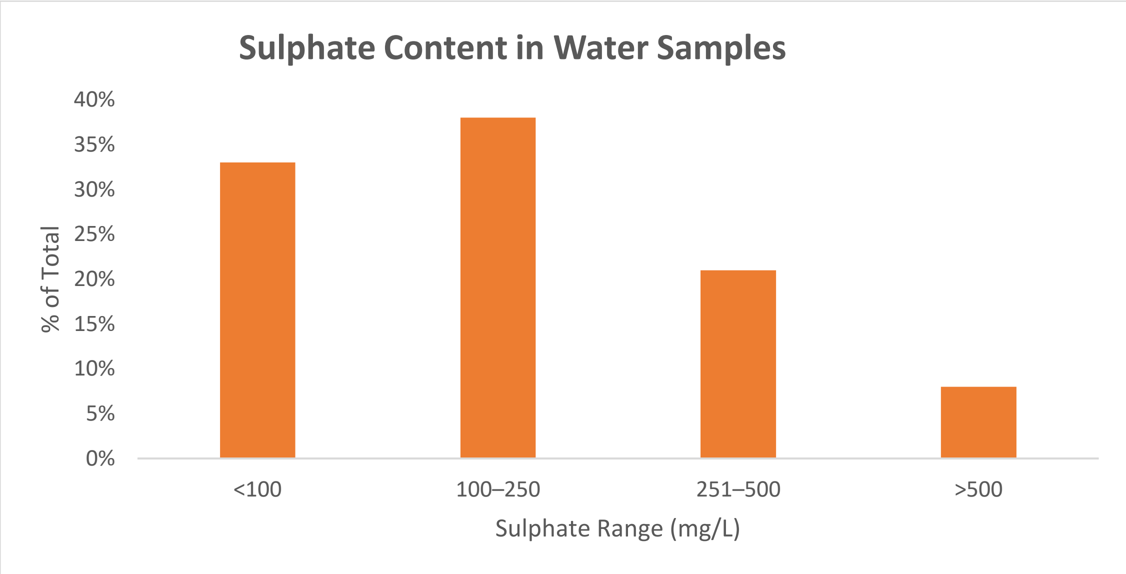
Figure 9: Sulphate Content in Water Samples



Source: Table 10

Lead (Pb) Contamination in Water Samples

Lead is a toxic heavy metal and is not naturally required by poultry or humans. Its presence in drinking water is a major health concern, as even low concentrations can lead to chronic toxicity, neurological issues and organ dysfunction. In poultry, lead exposure can result in impaired growth, reduced feed intake, poor egg quality and immunosuppression. According to WHO standards, the acceptable limit for lead in drinking water is 0.01 mg/L (10 µg/L).

Table 11: Statistical Summary of Lead Presence in Water Samples (n = 100)

Lead Level	No. of Samples	% of Total	Detection Status	WHO Standard	Status
Not Detected (ND)	67	67%	No yellow color observed	<0.01 mg/L	Safe – No contamination
Detected: Trace (<0.05)	21	21%	Faint yellow color	Exceeds WHO	Low risk – Monitor regularly
Detected: Moderate (0.05–0.1)	9	9%	Yellow color distinct	Exceeds WHO	Moderate risk – Requires filtration
Detected: High (>0.1 mg/L)	3	3%	Dark yellow color	Exceeds WHO	High risk – Unsafe for poultry & humans

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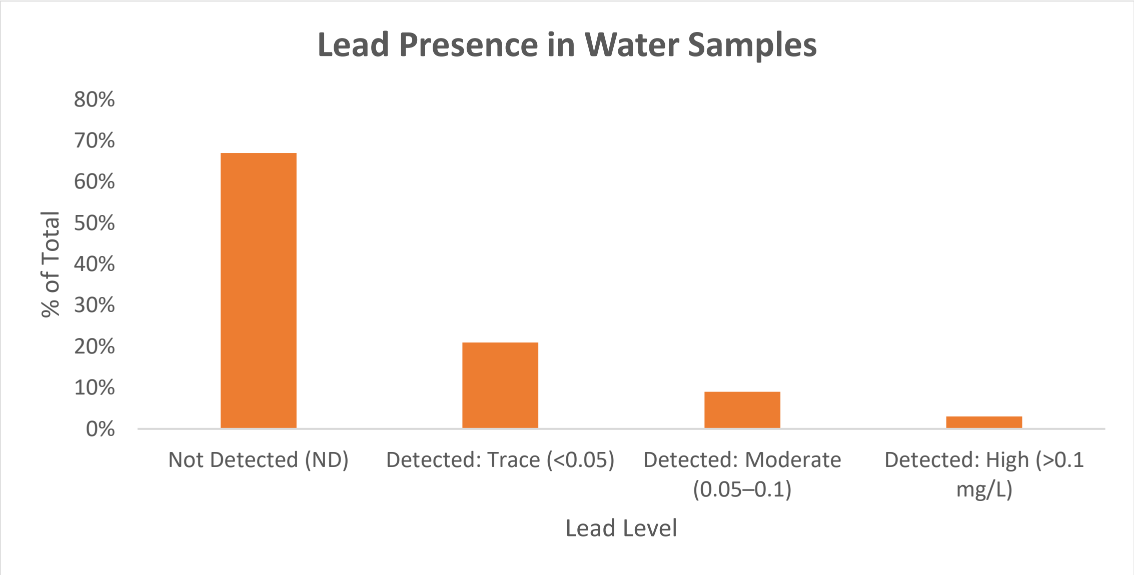
Figure 10: Lead Presence in Water Samples



Source: Table 11

Discussion

The quality of drinking water plays a pivotal role in determining the health, productivity and overall performance of poultry. In this study, extensive analysis of physicochemical and microbiological parameters across 100 poultry farms in Haryana revealed several pressing concerns regarding groundwater safety. The results clearly indicate that while some parameters fell within acceptable limits, a significant number exceeded national and international safety standards, thereby posing direct and indirect threats to poultry health and production economics.

The pH levels of the analyzed water samples were largely within the acceptable range, with 81% falling between 6.5 and 8.5. However, the presence of acidic (below 6.5) and alkaline (above 8.5) samples, comprising 12% and 7% respectively, cannot be ignored. Acidic water may lead to pipeline corrosion, releasing toxic metals such as lead and copper into the water, while alkaline water can reduce the solubility of essential minerals like calcium and phosphorus. Both conditions can significantly affect digestion, bone development and eggshell formation in poultry. The stability of pH in the majority of samples is encouraging, but even small deviations from the optimal range warrant attention due to their cascading effects on bird health and nutrient bioavailability.

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The Total Dissolved Solids (TDS) content of the water samples presented a more concerning picture. Just under half of the samples (44%) had TDS levels below 500 mg/L, deemed safe and palatable for poultry. However, 38% of the samples had TDS levels in the marginal range of 501–1000 mg/L, while 15% exceeded 1000 mg/L, falling into the brackish category. High TDS levels are often indicative of salinity and the presence of multiple dissolved ions, including sodium, chloride and sulfates. In poultry, brackish water can lead to dehydration, reduced feed conversion efficiency, increased susceptibility to disease and even mortality in extreme cases. These issues are particularly pronounced in the arid and semi-arid regions of Haryana, such as Hisar and Sirsa, where groundwater salinity is naturally higher.

Hardness, primarily caused by dissolved calcium and magnesium salts, was another parameter with significant deviation from acceptable standards. Only 48% of the samples fell within the ideal range (<150 mg/L), while the remaining 52% exceeded it, including 20% with levels above 300 mg/L. High hardness impacts the effectiveness of antibiotics, contributes to scale formation in pipelines and reduces water hygiene by encouraging microbial biofilm formation. Poultry consuming hard water may experience reduced nutrient absorption, kidney stress and metabolic imbalances. The geographical correlation between high hardness levels and semi-arid zones underscores the need for region-specific water management strategies.

Calcium carbonate content ($CaCO_3$), a contributing factor to both hardness and alkalinity, was above or below the optimal range in 57% of the samples. Only 44% of the samples were within the desirable range of 75–200 mg/L. Elevated levels of $CaCO_3$ can disrupt the calcium-phosphorus balance, reduce the availability of phosphorus and cause urinary tract complications such as gout in poultry. These mineral imbalances can severely affect eggshell strength and skeletal development, especially in laying hens and breeder stock. Furthermore, high $CaCO_3$ concentrations were observed in areas with lime-rich aquifers, suggesting that local geology significantly influences water chemistry.

Nitrate and nitrite contamination were also notable. While nitrate levels exceeded the WHO limit of 50 mg/L in 27% of the samples, nitrite levels surpassed the threshold of 3 mg/L in 12% of the samples. These contaminants typically originate from agricultural runoff, sewage, or decomposed organic waste. In poultry, high nitrate and nitrite levels can impair oxygen transport in the blood, reduce feed intake and slow down weight gain. The health risks are particularly high for chicks and young birds, who are more vulnerable to nitrate-induced toxicity. The proximity of farms to agricultural fields and unregulated sewage disposal practices likely contribute to this contamination.

Chloride concentration, an important indicator of salinity, was within the acceptable range (100–250 mg/L) in 48% of the samples and below 100 mg/L in 26%. However, 26% of the samples exceeded 250 mg/L, with 8% crossing the 500 mg/L mark. Elevated chloride levels can lead to unpalatable drinking water, reduced water consumption and increased thermal stress during hot weather. Additionally, when combined with high sodium and bicarbonate levels, excessive chloride can cause severe electrolyte imbalances. Such conditions are detrimental to broiler performance and can increase mortality rates, especially in summer months.

Microbiological contamination was one of the most alarming findings in this study. Only 32% of the water samples were free of coliforms, while the remaining 68% ranged from slightly to heavily contaminated. Specifically, 16% of samples showed coliform counts exceeding 100 MPN/100 ml, indicating high fecal contamination. The presence of coliforms is a direct indicator of inadequate sanitation and possible ingress of pathogens like *E. coli* and *Salmonella*. Contaminated water not only causes gastrointestinal diseases but also creates biofilms in water lines, shielding bacteria from disinfectants and promoting chronic infections within poultry populations. The high rate of contamination was particularly prevalent in farms using open storage tanks and pipelines laid at ground level.

Total Viable Count (TVC) analysis further confirmed widespread microbial contamination. Only 29% of samples were within the safe limit of <100 CFU/ml. A significant 71% had elevated bacterial loads, with 15% exceeding 1000 CFU/ml, indicating critical contamination. TVC provides a cumulative measure of all live aerobic bacteria present and is a key indicator of general water hygiene. High TVC levels can disrupt the gut microbiome, reduce nutrient absorption and create favorable conditions for secondary infections. In poultry farms, such microbial burden can lead to slower growth, lower feed efficiency and higher antibiotic usage, thereby increasing production costs and the risk of antimicrobial resistance.

Sulphate content was within the safe range (≤250 mg/L) in 71% of the samples, while 29% exceeded the limit. Elevated sulphate levels can cause osmotic imbalance and diarrhea in birds, particularly when combined with high magnesium or sodium levels. This not only affects feed conversion efficiency but also increases moisture in litter, raising the risk of respiratory and

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footpad diseases. The western regions of Haryana, characterized by saline aquifers, reported the highest sulphate concentrations, aligning with known geohydrological patterns.

Lead contamination was found in 33% of the samples, although only 3% had concentrations exceeding 0.1 mg/L, which is considered highly toxic. Even trace amounts of lead can impair red blood cell formation, damage the nervous system and suppress immunity in poultry. The likely sources of lead include old galvanized pipelines, industrial runoff and agricultural chemicals. Continuous exposure, even at low levels, poses cumulative toxicity risks, affecting not just poultry but also humans through the food chain.

Fluoride content, another geogenically influenced parameter, was found to exceed the WHO safe limit (1.5 mg/L) in 15% of the samples. Chronic ingestion of fluoride can lead to skeletal deformities, poor reproductive performance and reduced growth in poultry. Birds consuming fluoride-contaminated water are also at higher risk for metabolic bone disease, especially if dietary calcium is not adequately balanced. The fluoride-rich samples were primarily from regions with high natural fluoride deposits in the aquifer rocks.

CONCLUSION

This research thoroughly evaluated the quality of groundwater from 100 poultry farms in Haryana and it found high deviations from WHO/BIS standards in a number of important parameters such as total dissolved solids, hardness, nitrate, sulphate, fluoride, microbial load and contamination with lead. The results illustrate poor water quality being a priority issue, where almost half of the samples were found to be brackish, with high microbial loads, as well as chemical contaminants that can significantly degrade poultry health, decrease growth performance and enhance mortality. Microbiological contamination, especially coliforms and elevated total viable counts, was alarmingly prevalent and was causing severe threats not just to poultry but also to human health by virtue of farm workers and their families sharing a common source of water. The research points towards the implicit correlation between contaminated water and decreased feed efficiency, poor weight gain and increased disease susceptibility in birds. These findings highlight the imperative necessity for frequent water quality testing, better infrastructure, uptake of treatment technologies and awareness programs among farmers to counteract health risks and productivity increases. By recognizing regional trends and linking water quality to bird performance, the study adds useful information for

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informing policy actions by intervention areas, in fostering improved sustainable poultry and enhancing wider public health and environmental protection aims in the state of Haryana.

Future Recommendations

Given the widespread deviations in water quality observed across multiple parameters, it is crucial to develop a multi-pronged, region-specific strategy to ensure water safety in poultry farms:

1. **Routine Water Quality Testing**: Farms should implement quarterly testing for physicochemical and microbiological parameters. This practice will help in early detection of any anomalies and allow for prompt corrective action.

2. **Water Treatment Systems**: Installation of suitable treatment technologies such as reverse osmosis, ultraviolet sterilization, activated carbon filtration and dechlorination systems should be encouraged. Special emphasis should be placed on areas with known high TDS, fluoride, sulphate, or lead levels.

3. **Source Protection and Sanitation**: Poultry farms must protect water sources from agricultural runoff, animal waste and sewage. Proper drainage systems, elevated pipelines and covered storage tanks should be mandated.

4. **Infrastructure Modernization**: Replacement of corroded or outdated plumbing with non-toxic, non-leaching materials is essential. This will minimize heavy metal contamination and improve the longevity of the water distribution system.

5. **Farmer Training and Awareness**: Farmers should be trained on the importance of water quality, how to interpret test reports and how to implement low-cost corrective measures. Government or institutional extension programs can play a pivotal role in this effort.

6. **Policy Intervention and Subsidy Support**: Government agencies should subsidize water testing kits, treatment units and rainwater harvesting systems. Policy frameworks should also mandate water quality audits as part of poultry farm registration or licensing.

7. **Integration with Feed and Health Management**: Water quality should be considered a core component of farm biosecurity plans, integrated with nutrition, vaccination and hygiene protocols to ensure holistic health management.

8. **Research and Data Repository**: A centralized database of water quality data, correlated with poultry performance metrics, should be developed for the region. This would enable predictive analytics and risk mapping for better resource planning.

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