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Analyzing physicochemical quality and coliform contamination risks in poultry drinking water of Indore (India)

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Abstract

There is great role of clean and safe drinking water in maintaining optimal poultry health and farm efficiency. The present study was conducted to evaluate physicochemical attributes and potential risk factors associated with coliform contamination in poultry water, across four blocks (Indore, Mhow, Depalpur, and Sanwer) of Indore district, Madhya Pradesh. A total of 120 water samples were collected randomly and analyzed for key parameters including temperature, pH, turbidity, total dissolved solids (TDS), colour, odour, taste, residual chlorine, total hardness, chloride, nitrate, fluoride, and iron content. Significant differences ($p < 0.05$) were observed among poultry water of blocks for temperature, pH, colour, residual chlorine, total hardness, chloride, nitrate, fluoride, and iron levels. Most water samples were odourless, with 73.33% in Indore, 60.67% in Mhow, and 60.00% in Depalpur. Taste quality varied, with 66.67% and 73.33% of water samples from Mhow and Sanwer respectively deemed to be favorable, while 16.67% of samples from Indore and Depalpur were rated as very unfavorable. Although parameters such as temperature, colour, TDS, residual chlorine, chloride, fluoride, and iron were within standard limits. While pH, turbidity, total hardness, and nitrate levels exceeded permissible values. These variations can have detrimental effects on bird health, feed efficiency, and overall farm productivity. Univariate analysis of potential risk factors related to coliforms contamination in poultry water showed that chlorination (OR = 0.36, 95% CI: 0.16-0.81, $p = 0.012$), regular cleaning of equipment (OR = 0.24, 95% CI: 0.11-0.53, $p = 0.001$), satisfactory water pH (OR = 0.24, 95% CI: 0.11-0.52, $p = 0.001$), acceptable total hardness (OR = 0.44, 95% CI: 0.21-0.92, $p = 0.027$), and antibiotic treatment of water (OR = 0.32, 95% CI: 0.13-0.79, $p = 0.011$) significantly reduced coliforms occurrence, while sampling site and water source showed no significant association ($p > 0.05$). Multivariate analysis revealed no statistically significant association ($p > 0.05$) between potential risk factors and the presence of coliform bacteria in poultry water. However, chlorination emerged as a critical factor for microbial safety (OR = 2.005, 95% CI = 0.946-4.246, $p = 0.069$), while total hardness showed a potential protective effect (OR = 0.599, 95% CI = 0.279-1.289, $p = 0.190$). These findings highlight the need for regular monitoring and proper water treatment to ensure poultry health in the region.

Keywords: Coliforms contamination, physicochemical, poultry, water, risk factors

Introduction

Water is essential in poultry farming for drinking, feeding, cleaning, temperature regulation, and administering medications and vaccines (Gama *et al.*, 2008; Folorunso *et al.*, 2014) [18, 16]. On average, birds generally consume two times more water than feed on weight basis, and intake increases significantly with rising temperatures (Blake and Hess, 2001; Travel *et al.*, 2007) [9, 35]. Ideal poultry drinking water should be neutral in pH (6.8-7.5), low in turbidity (<5 NTU), and free from colour, odour, and taste (Carter and Sneed, 1998; Fairchild and Ritz, 2009; Sheikh, 2019) [11, 14, 31]. Poor-quality water can damage equipment and reduce flock performance. High salinity and hardness can lead to health problems such as diarrhea, vomiting, and kidney issues (NRC, 2006; Purohit *et al.*, 2004) [23, 27]. Elevated nitrates, fluoride, and iron also pose risks like methemoglobinemia, fluorosis, and mineral absorption interference (Schutz, 2012; Patil *et al.*, 2012; Beede, 2009) [29, 26, 6]. Microbial contamination, especially from coliforms like *Escherichia coli*, is a major concern, indicating fecal pollution and leading to diseases such as colibacillosis, enteritis, and yolk sac

infections (Ahmad *et al.*, 2009; Rosenberger *et al.*, 1985) [1, 28]. Monitoring water for both physicochemical and microbial quality is therefore vital. This study aimed to assess physicochemical properties and potential risk factors for coliforms contamination in poultry farm's water of Indore district (India).

Materials and Methods

Sampling: A total of 120 water samples were collected randomly from poultry farms in four blocks of Indore district, Madhya Pradesh (Indore, Mhow, Sanwer, Depalpur) between June and November 2024 (30 samples per block). Samples were collected in polypropylene bottles, transported in ice boxes, and stored at 4 °C for physicochemical analysis. Bacteriological tests were done within 24 hours following standard protocols (Park, 2011) [25].

Chemicals and media: Analytical-grade chemicals and reagents including pH buffers, 0.2M EDTA, potassium chromate, silver nitrate, and N, N-diethyl-p-phenylenediamine (DPD) were used. Microbiological media like Mac Conkey broth and EMB agar were employed.

Glass ware, plastic ware and equipments: Plastic ware from Tarsons and glassware from Borosil were used. Instruments included a hot air oven, incubator, autoclave, bio-safety cabinet, and pH meter along with standard lab materials.

Assessment of physico-chemical attributes of water: Parameters like temperature, pH, colour, odour, taste, turbidity, total dissolved solids (TDS), residual chlorine, total hardness (TH), chloride, nitrate, fluoride and iron, were evaluated by standard methods (Table 1).

Table 1: Methodologies adopted for assessing physico-chemical parameters of poultry water

S. No.	Parameter	Methodology	Reference
1.	Temperature	On-site measurement using mercury thermometer	APHA, 1995 [3]
2.	pH	Electrometric method with pH meter	Gupta, 2009 [20]
3.	Colour	Visual comparison with platinum-cobalt standards (Hazen method)	FSSAI, 2016 [17]
4.	Odour	Sensory/organoleptic evaluation	FSSAI, 2016 [17]
5.	Taste	Sensory evaluation/organoleptic method	FSSAI, 2016 [17]
6.	Turbidity	Nephelometric method	FSSAI, 2016 [17]
7.	Total Dissolved Solids	Gravimetric method (evaporation and drying in oven)	FSSAI, 2016 [17]
8.	Residual Chlorine	DPD (N,N-Diethyl-p-phenylenediamine) colorimetric method	FSSAI, 2016 [17]
9.	Total Hardness	EDTA titrimetric method	APHA, 1995 [3]
10.	Chloride	Argentometric titration	APHA, 1995 [3]
11.	Nitrate	Colorimetric method	Sharma, 2016 [30]
12.	Fluoride	Colorimetric method	Sharma, 2016 [30]
13.	Iron	Colorimetric method	Sharma, 2016 [30]

Risk factors investigation for coliforms contamination in poultry water: A random sampling technique was employed to interview 120 poultry farmers who consented to participate in the study. Alongside the collection of water samples for physicochemical analyses, farms were evaluated for potential risk factors affecting water quality with coliforms contamination. These factors included sampling site, chlorination, equipment cleaning, pH, total hardness, antibiotic treatment, and water sources.

Coliforms bacteria, particularly *Escherichia coli*, serve as critical indicators of fecal contamination in water, signaling possible pollution with pathogenic microorganisms and harmful substances. Assessing coliforms presence is essential to estimate recent fecal contamination in drinking water sources. Here, coliforms enumeration was performed using the Most Probable Number (MPN) method as described by the American Public Health Association (APHA, 1998) [4].

Statistical analysis

Physicochemical parameters were statistically analyzed using one-way analysis of variance (ANOVA) following Snedecor and Cochran (1994) [33]. Risk factors associated with coliforms contamination were evaluated using chi-square tests and logistic regression analysis with SPSS software version 20.

Results

Physicochemical quality of poultry drinking water: The physicochemical characteristics of poultry drinking water from four blocks of Indore district viz Indore, Mhow, Sanwer and Depalpur were analyzed to assess its suitability for poultry health. Among the 13 tested parameters, 9 exhibited statistically significant variation ($p < 0.05$) across the study blocks, namely: temperature, pH, colour, residual chlorine, total hardness, chloride, nitrate, fluoride and iron (Table 2).

Table 2: Mean values of physicochemical parameters of poultry water (Mean±SE)

Blocks Parameter	Indore	Mhow	Sanwer	Depalpur	District Mean
Temperature (°C)	26.70 ^a ±0.13	25.60 ^b ±0.12	25.50 ^b ±0.17	25.48 ^b ±0.16	25.83±0.08
pH	7.52 ^{ac} ±0.09	7.67 ^a ±0.09	7.26 ^b ±0.11	7.44 ^c ±0.13	7.48±0.05
Colour (Hazen)	12.50 ^a ±0.54	10.80 ^b ±0.45	13.70 ^a ±0.71	12.90 ^a ±0.74	12.47±0.32
Turbidity	5.02±0.15	5.08±0.32	4.52 ^{ac} ±0.34	5.62±0.26	5.06±0.34
TDS	481.00±37.30	406.03±22.91	498.40±47.01	465.00±39.90	464.45±18.82
Residual Chlorine (mg/L)	0.20 ^b ±0.06	0.12 ^b ±0.05	0.15 ^b ±0.06	0.46 ^a ±0.14	0.21±0.02
Total Hardness (mg/L)	256.03 ^b ±17.87	297.00 ^a ±7.96	251.00 ^b ±7.91	239.00 ^b ±6.52	278.70±8.48
Chloride (mg/L)	128.56 ^a ±9.36	222.00 ^b ±13.00	157.24 ^{ac} ±8.72	180.00 ^c ±12.10	171.48±6.11
Nitrate (mg/L)	85.60 ^a ±4.28	67.60 ^b ±3.77	89.50 ^a ±4.36	56.10 ^c ±3.64	74.95±2.31
Fluoride (mg/L)	0.43 ^a ±0.05	0.69 ^b ±0.07	0.83 ^b ±0.05	0.51 ^a ±0.06	0.54±0.02
Iron (mg/L)	0.27 ^a ±0.04	0.17 ^b ±0.02	0.13 ^b ±0.02	0.11 ^b ±0.01	0.16±0.01

Note: Superscripts (a, b, c) denote statistically significant differences within rows ($p < 0.05$) based on ANOVA and post-hoc analysis.

Poultry drinking water temperatures in Indore, Mhow, Sanwer, and Depalpur blocks were found to be ranged from 25.60-27.40 °C, 24.60-27.70 °C, 25.00-27.80 °C, and 24.30-27.50 °C, respectively. The corresponding mean values were 26.70 ± 0.13 °C (Indore), 25.60 ± 0.12 °C (Mhow), 25.50 ± 0.17 °C (Sanwer), and 25.48 ± 0.16 °C (Depalpur), with Indore showing the highest mean temperature. The overall district mean was 25.83 ± 0.08 °C (Table 2).

The pH of poultry drinking water was found to be ranged from 6.7-8.1 (Indore), 6.8-8.2 (Mhow), 6.6-8.0 (Sanwer), and 6.9-8.3 (Depalpur), with mean values of 7.52 ± 0.09, 7.67 ± 0.09, 7.26 ± 0.11, and 7.44 ± 0.13, respectively. Mhow recorded the highest mean pH, while Sanwer had the lowest. The overall mean pH for Indore district was 7.48 ± 0.05. ANOVA revealed significant variation in pH

values across blocks ($p < 0.05$) (Table 2).

The colour of poultry drinking water ranged from 5.00 to 20.00 Hazen units, with mean values of 12.50 ± 0.54 (Indore), 10.80 ± 0.45 (Mhow), 13.70 ± 0.71 (Sanwer), and 12.90 ± 0.74 (Depalpur). Sanwer recorded the highest mean, while Mhow had the lowest. The overall district mean was 12.47 ± 0.32 Hazen units. ANOVA showed significant variation among blocks ($p < 0.05$) (Table 2).

Out of all poultry water samples analyzed, 63.33% were found to be odourless, 12.50% had a vegetable-like odour, 13.33% exhibited an earthy odour, and 10.83% showed a chemical/medicinal odour. A higher proportion of odourless samples were recorded in the Indore block (73.33%) compared to Mhow (60.67%) (Table 3).

Table 3: Odour of poultry water samples in studied area

Characteristics	Indore n = 30	Mhow n = 30	Sanwer n = 30	Depalpur n = 30	Overall Percentage n = 120
Odourless	22 (73.33)	20 (60.67)	16 (53.33)	18 (60.00)	76 (63.33)
Earthy	1 (3.33)	5 (16.66)	6 (20.00)	4 (13.33)	16 (13.33)
Vegetables	1 (3.33)	3 (10.00)	6 (20.00)	5 (16.67)	15 (12.50)
Chemical/medicinal	6 (20.00)	2 (6.66)	2 (6.66)	3 (10.00)	13 (10.83)
Fishy	00	00	00	00	00

* Values given in parentheses indicates percentage

Overall, 63.33% of water samples were found to be favorable for poultry consumption. Block-wise, the samples with favorable taste was found to be highest in Sanwer

(73.33%) and Mhow (66.67%), while 16.67% of samples from Depalpur and Indore were rated as very unfavorable (Table 4).

Table 4: Taste of poultry water samples in studied area

Characteristics	Indore n = 30	Mhow n = 30	Sanwer n = 30	Depalpur n = 30	Overall Percentage n = 120
Very favourable	3 (10.00)	3 (10.00)	1 (3.33)	2 (6.67)	9 (7.50)
Favourable	18 (60.00)	20 (66.67)	22 (73.33)	16 (53.33)	76 (63.33)
Unfavourable	4 (13.33)	4 (13.33)	5 (16.67)	7 (23.33)	20 (16.67)
Very unfavourable	5 (16.67)	3 (10.00)	2 (6.67)	5 (16.67)	15 (12.50)

* Values given in parentheses indicate percentages

Turbidity levels in poultry water were found to be ranged from 4.0 to 6.0 NTU, with block-wise means of 5.02 ± 0.15 NTU (Indore), 5.08 ± 0.32 NTU (Mhow), 4.52 ± 0.34 NTU (Sanwer), and 5.62 ± 0.26 NTU (Depalpur). The differences among blocks were not statistically significant ($p > 0.05$), with an overall mean of 5.06 ± 0.34 NTU for Indore district (Table 2).

TDS levels in poultry water samples were found to be ranged from 15.00 to 755.00 ppm. Mean values were 481.00 ± 37.30 ppm (Indore), 406.03 ± 22.91 ppm (Mhow), 498.40 ± 47.01 ppm (Sanwer), and 465.00 ± 39.90 ppm (Depalpur), with no significant variation among blocks. The overall mean for the district was 464.45 ± 18.82 ppm (Table 2). The highest TDS was observed in Sanwer, and the lowest in Mhow block.

RC levels in poultry water samples were found to be ranged from 0 to 0.60 mg/L. The highest mean RC was observed in Depalpur block (0.46 ± 0.14 mg/L), while the lowest was in Mhow block (0.12 ± 0.05 mg/L). The overall mean RC in

Indore district was 0.21 ± 0.02 mg/L (Table 2). ANOVA indicated significant differences ($p < 0.05$) among blocks.

TH of poultry water samples varied across blocks, with mean values of 297.00 ± 7.96 mg/L in Mhow, 256.03 ± 17.87 mg/L in Indore, 251.00 ± 7.91 mg/L in Sanwer, and 239.00 ± 6.52 mg/L in Depalpur. The overall mean TH for Indore district was 278.70 ± 8.48 mg/L (Table 2). Statistical analysis showed significant variation in TH among the different blocks ($p < 0.05$).

Chloride levels in poultry water samples were found to be ranged from 80.00 to 400.00 mg/L. Mean values were 222.00 ± 13.00 mg/L in Mhow, 180.00 ± 12.10 mg/L in Depalpur, 157.24 ± 8.72 mg/L in Sanwer, and 128.56 ± 9.36 mg/L in Indore. The overall mean chloride concentration across the district was 171.48 ± 6.11 mg/L (Table 2). ANOVA indicated a significant difference ($p < 0.05$) among the blocks.

Nitrate levels in poultry water samples were found to be ranged from 0 to 175 mg/L. Mean concentrations were

highest in Sanwer (89.50 ± 4.36 mg/L), followed by Indore (85.60 ± 4.28 mg/L), Mhow (67.60 ± 3.77 mg/L), and Depalpur (56.10 ± 3.64 mg/L). The overall mean nitrate level in the Indore district was 74.95 ± 2.31 mg/L (Table 2). ANOVA revealed a significant difference ($p < 0.05$), particularly between Sanwer and the other blocks.

Fluoride levels in poultry water samples were found to be ranged from 0 to 1.00 mg/L. The highest mean value was observed in Sanwer (0.83 ± 0.05 mg/L), followed by Mhow (0.69 ± 0.07 mg/L), Depalpur (0.51 ± 0.06 mg/L), and Indore (0.43 ± 0.05 mg/L). The overall mean fluoride concentration in the Indore district was 0.54 ± 0.02 mg/L (Table 2). ANOVA revealed a significant difference in fluoride levels across the blocks ($p < 0.05$).

Iron levels in poultry water samples were found to be ranged from 0 to 0.4 mg/L. The highest mean concentration was recorded in Indore (0.27 ± 0.04 mg/L), followed by Mhow (0.17 ± 0.02 mg/L), Sanwer (0.13 ± 0.02 mg/L), and Depalpur (0.11 ± 0.01 mg/L). The overall mean iron level across Indore district was 0.16 ± 0.01 mg/L (Table 2). ANOVA revealed a significant difference ($p < 0.05$) between Indore and the other blocks.

Risk factor investigation for coliforms contamination in poultry farm's water: The association between potential risk factors and coliforms occurrence in poultry water was analyzed using chi-square tests (Uni-variate analysis) (Table 5). Sampling site (beginning of nipple line) showed a non-significant association with coliforms occurrence ($p > 0.05$; OR = 1.87, 95% CI: 0.82-4.28). Chlorination was significantly associated with reduced coliforms occurrence ($p < 0.05$; OR = 0.36, 95% CI: 0.16-0.81). Cleaning of equipment also showed a significant protective effect ($p < 0.05$; OR = 0.24, 95% CI: 0.11-0.53). Water pH was significantly associated, with satisfactory pH reducing

coliforms occurrence ($p < 0.05$; OR = 0.24, 95% CI: 0.11-0.52). Total hardness was significantly related, where satisfactory hardness decreased coliforms presence ($p < 0.05$; OR = 0.44, 95% CI: 0.21-0.92). Antibiotic treatment of water significantly reduced coliforms contamination ($p < 0.05$; OR = 0.32, 95% CI: 0.13-0.79). Water source (bore water) had no significant effect on coliforms occurrence ($p > 0.05$; OR = 1.08, 95% CI: 0.49-2.37).

In the present study, a multivariate analysis (binary logistic regression) was also performed using the variables that showed a p -value < 0.2 in the univariate analysis. The variables included in the multivariate model were sampling site, chlorination, cleaning of equipment, pH limit, total hardness and antibiotic treatment. The results showed that none of the risk factors significantly associated ($p > 0.05$) with the occurrence of coliforms in poultry farm water (Table 6). The key findings of multivariate model were as follows:

Chlorination was found to be the most significant predictor in the model. Although the p -value ($p = 0.069$) is marginally above the conventional 0.05 significance threshold, it indicates a trend toward statistical significance. The odds ratio (OR = 2.005) suggests that the absence of chlorination increases the likelihood of coliforms occurrence by approximately 2 times, compared to water sources that are chlorinated. Total hardness had a p -value of 0.190 and an odds ratio of 1.599. While this variable was not statistically significant, the OR suggests a potential protective effect, implying that higher water hardness might be associated with a lower risk of coliforms contamination. However, this relationship requires further investigation. The other analyzed variables indicate no statistically significant association with coliforms contamination in this multivariate model.

Table 5: Univariable analysis of risk factors associated with occurrence of coliform in poultry farm water (n = 120)

S. No.	Variable	Category	Coliform Present	Coliform Absent	Odds ratio (OR)	95% CI	P value
1.	Sampling site	Present	17	35	1.87	0.82-4.28	0.133
		Absent	14	54			
2.	Chlorination	Present	12	26	0.36	0.16-0.81	0.012
		Absent	46	36			
3.	Cleaning of equipments	Present	18	57	0.24	0.11-0.53	0.001
		Absent	27	18			
4.	pH limit	Satisfactory	16	38	0.24	0.11-0.52	0.001
		Unsatisfactory	42	24			
5.	Total hardness limit	Satisfactory	20	32	0.44	0.21-0.92	0.027
		Unsatisfactory	40	28			
6.	Antibiotic treatment	Present	8	37	0.32	0.13-0.79	0.011
		Absent	30	45			
7.	Water source	Present	20	45	1.08	0.49-2.37	0.842
		Absent	16	39			

CI = Confidence Interval

Table 6: Multivariable analysis of risk factors associated with the occurrence of coliform in poultry farm water

S. No.	Variable	Odds Ratio	95% CI	p-value
1	Sampling site	1.559	0.732-3.319	0.250
2	Chlorination	2.005	0.946-4.246	0.069
3	Cleaning of equipments	1.181	0.554-2.521	0.666
4	pH limit	0.738	0.342-1.588	0.437
5	Total Hardness	0.599	0.279-1.289	0.190
6	Antibiotic Treatment	1.388	0.659-2.923	0.389

Discussion

The current study was conducted to evaluate physicochemical attributes of poultry water. For temperature parameter, most water samples fell within the WHO (2008) [36] recommended range of 25-27 °C. Minor variations may be linked to redox reactions due to contamination. The results of present study are in line with Yirga *et al.* (2019) [37], who observed no significant site-wise temperature differences, and Budholiya (2023) [10], who reported a mean of 26.32 °C for livestock water in the same region.

pH of most poultry water samples was found within the permissible range of 6.5-7.5 recommended by Carter and Sneed (1998) ^[11]. Variations may be attributed to impurities or environmental interactions. The results are partially consistent with Osei *et al.* (2019) ^[24], who reported a broader pH range (3.76-8.90), and align with Budholiya (2023) ^[10], who reported a mean pH of 7.27 for livestock water in the region.

Colour of most water samples was within the BIS (2012) ^[8] permissible range of 5-15 Hazen units. Variations may result from dissolved/suspended matter and contamination from anthropogenic or industrial sources. These results contrast with Thirunavukkarasu (1997) ^[34], who reported lower colour values, but are comparable to Budholiya (2023) ^[10], who found a mean of 11.91 Hazen units in livestock water.

The findings for odour of poultry water were partially aligned with Lugomer *et al.* (2017) ^[21], who reported most microbiologically suitable samples as odourless. Odour, an important sensory parameter, can indicate contamination; however, most samples in this study conformed to BIS (2012) ^[8] standards.

The results for taste of water were partially consistent with Budholiya (2023) ^[10], who reported 55.83% of livestock water samples as favourable. The variation in taste may be linked to differences in local geology and contamination levels. Most samples met BIS (2012) ^[8] guidelines for taste.

The values for turbidity in poultry water was found to be slightly exceeded the BIS (2012) ^[8] permissible limit of 2-4 NTU and are partially consistent with the findings of Garg *et al.* (2009) ^[19], who reported turbidity levels between 2.17 and 16.72 NTU. Elevated turbidity may be due to suspended particulates such as clay, silt, colloids, and microbial matter.

The findings for TDS are found to be consistent with previous studies by Osei *et al.* (2019) ^[24], Mobin *et al.* (2014) ^[22], and Budholiya (2023) ^[10], all reporting TDS values within comparable ranges. In this study, TDS levels remained less than 1000 ppm which is reported to be unproblematic for poultry water (FAO, 2016) ^[15].

The RC levels observed in this study align with findings by Shrestha *et al.* (2017) ^[32], who reported values between 0.10 and 0.50 mg/L in drinking water. All measured values were below the permissible limit of 2-3 mg/L set by Carter and Sneed (1998) ^[11], indicating that the poultry water samples were within safe chlorine levels.

TH levels in this study exceeded the recommended upper limit of 180 mg/L for poultry water (Carter and Sneed, 1998) ^[11], and were higher than those reported by Osei *et al.* (2019) ^[24], who found values ranging from 17.10 to 192.00 mg/L. The elevated TH may be attributed to the region's geology, particularly calcium-rich sedimentary rocks, and the use of lime in agriculture.

Chloride concentrations observed in this study were considerably lower than those reported by Bharathy *et al.* (2019) ^[7] as 655.75 ± 76 mg/L and Thirunavukkarasu (1997) ^[34], who found chloride levels of 375.75 ± 49 mg/L in open wells and 326.5 ± 37 mg/L in drilled wells. All samples in the current study remained within the permissible limits for poultry water, as recommended by Carter and Sneed (1998) ^[11].

The nitrate levels observed in this study were significantly higher than those reported by Djefell *et al.* (2024) ^[12] as 2.61 ± 4.28 mg/L and Bharathy *et al.* (2019) ^[7] as 7.01 ± 1.48 mg/L. Most samples exceeded the permissible

limit of 25 mg/L for poultry water, as prescribed by Carter and Sneed (1998) ^[11]. Elevated nitrate concentrations may result from contamination due to fertilizers, industrial effluents, decaying organic matter, and animal waste.

Fluoride concentrations in the present study were found to be higher than those reported by Fadaei and Sadeghi (2014) ^[13], who observed mean levels of 0.20 ± 0.1 mg/L. However, all values remained well below the permissible limit of 2 mg/L for poultry water, as prescribed by Carter and Sneed (1998) ^[11], indicating the safety of the water samples with respect to fluoride content.

The iron levels observed in current study were consistent with those reported by Bharathy *et al.* (2019) ^[7], who found a mean value of 0.27 ± 0.08 mg/L. All samples in the current study were within the permissible limit of 0.3 mg/L for poultry water as per Carter and Sneed (1998) ^[11]. Elevated levels in some samples may be attributed to iron-rich soil and organic matter in the region.

The present study also investigated risk factors for coliforms contamination in poultry water. On chi-square analysis, the study identified several significant factors influencing coliforms contamination in poultry drinking water. Chlorination, equipment cleaning, satisfactory pH, total hardness, and antibiotic treatment were all found to be associated with a significantly reduced likelihood of coliforms occurrence. These findings support previous studies (Allaoui *et al.*, 2016; Augusto *et al.*, 2022) ^[2, 5] highlighting the importance of water treatment and hygiene practices in controlling microbial contamination. The non-significant association of sampling site and water source with coliforms presence suggests that contamination is more influenced by on-farm management than by the point of water collection or source type. The significant effects of pH and total hardness observed here contrast with earlier reports (Allaoui *et al.*, 2016; Augusto *et al.*, 2022) ^[2, 5]. This discrepancy may arise from local geological conditions, bio-film formation facilitated by water hardness, or differences in poultry management practices affecting water quality. Overall, maintaining effective chlorination, regular equipment cleaning, appropriate water pH and hardness, and antibiotic treatments appear critical for reducing coliforms contamination in poultry farm water systems.

On multivariate analysis, the findings of present study about risk factors associated with coliforms occurrence in poultry water can be corroborated with the previous findings of Augusto *et al.* (2022) ^[5], who performed the multivariate logistic regression model and found that none of the risk factors were significantly associated with the occurrence of total coliforms in laying hens drinking water. Our study is aligned with these findings.

Conclusion

The findings of this study showed that the mean values for physicochemical parameters of poultry water such as temperature, colour, TDS, residual chlorine, chloride, fluoride and iron were found within the permissible limits. The results indicated that the parameters of poultry water like pH, turbidity, total hardness and nitrate levels were found to be exceeded the allowable limits. These deviations can have detrimental effects on bird health, feed efficiency, and overall farm productivity. Chlorination stands out as a critical risk factor for controlling coliforms occurrence in poultry drinking water. Total hardness indicated a possible protective effect, though not significant. Other risk factors

showed no meaningful associations concerned with occurrence of coliforms in poultry water.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: All data underlying the results are included in the article; no additional source data is required.

Ethical statement: This study was approved by Institutional Animal Ethics Committee, Veterinary College, Mhow (M.P.)

Author's contribution: Dr. AS—Method validation and laboratory analysis; Dr. VK—help in design of study and research methodology; Dr. RST—help in experimental design and set up; Dr. NKN—help in lab investigation and data analysis; Dr. S.P.S.P.—help in field investigation and data collection; Dr. S.P.Y. —help in field investigation and data collection.

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