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Water Quality of Borehole and Shallow Wells Feeding Artificial Fish Ponds in Bechar Province, Southwestern Algeria: Bacteriological and Physicochemical Aspects

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ABSTRACT

Background: This study aimed to assess the bacteriological and physicochemical properties of the water supplying the artificial concrete fish ponds in Bechar province (Southwestern Algeria).

Methods: Bacteriological and physicochemical parameters were assessed using standard procedures for water and wastewater analysis, as outlined by the APHA and WEF.

Result: Physicochemical analysis showed that water temperatures ranged from 18 to 21°C, with a neutral to slightly alkaline pH (7.4 to 8.53). Electrical conductivity (EC) varied from 1313 to 3848 µS/cm and the water was classified as hard, with total hardness (TH) ranging from 297 to 873 mg/L. Bacteriological analysis revealed that 13 of the 21 samples (62%) complied with national regulations, while 8 samples (38%) were contaminated with fecal coliforms, fecal streptococci and sulfite-reducing *Clostridia* (SRC) spores. Five samples (Sb7, Sb8, St15, St16, St17) and one sample (Sb7) were contaminated with *Pseudomonas* spp and *Salmonella* spp, respectively. Among the 21 samples analyzed, 16 had a total aerobic mesophilic flora (TAMF) load ranging from 2 to 4 Log_{10} CFU/mL at 22°C, while the remaining 5 had a TAMF load below 2 Log_{10} CFU/mL. Pathogen identification revealed the presence of *Salmonella choleraesuis* ssp. *arizonae* and *Pseudomonas aeruginosa*. We observed that the contaminated samples originated from the elevated water storage tank in Boukais and from some shallow well samples in Taghit, whereas borehole samples from Nif-Rhaa (Ouakda) and Boukais showed good microbiological quality. Further investigation is needed to identify the source of water contamination. Ensuring water quality is essential for safe aquaculture practices, which contribute to high-quality fish production and national food safety strategies.

Key words: Bacteriological parameters, Fish farming, Physicochemical parameters, Water.

INTRODUCTION

Aquaculture represents a true tool for economic diversification, serving as a source of employment, income and livelihoods for countries. It is not limited to coastal areas but also extends to inland communities, where fish farming ensures a vital food supply (ILO, 2021). According to the International labour organization (ILO), China alone accounts for 57.76% of global production. Following China are Indonesia, India, Vietnam and Bangladesh, which contribute 12.9%, 6.18%, 3.63% and 2.1%, respectively.

Egypt (1.36%) is the only African country among the top 15 producers, ranking 8th globally. This success has encouraged Algerian authorities to initiate partnership agreements with Egypt, aiming to develop Saharan aquaculture in Algeria's southern regions. The goal is to enhance food security in response to rapid population growth, meet local dietary preferences and create sustainable employment opportunities. According to the FAO (Horizons Magazine, 2024), Algeria's annual aquaculture production ranges between 6,000 and 7,000 tons per year. With 200 registered aquaculture projects, the country aims to achieve 100,000 tons by 2030. This economic activity contributes to food security, food safety and, from a nutritional perspective, fish provide a balanced diet rich in proteins, vitamins and fats for consumers (Adebami *et al.,* 2020; Abbani *et al.,* 2022).

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Given the limited water resources in Algeria's arid and semi-arid regions, integrated aquaculture systems are increasingly being adopted for sustainable water use (Abbani *et al.,* 2022; Mramba and Kahindi, 2023; Mondal *et al.,* 2025). However, the physicochemical and bacteriological properties of the water used in aquaculture operations, particularly in non-coastal regions, play a crucial role in the success of this activity (Eghomwanre *et al.,* 2019; Nair and Nayak, 2023).

Bacterial indicators such as coliforms and fecal streptococci are essential to assess microbiological contamination, as they signal the potential presence of pathogens capable of causing diseases in fish and humans (Tyagi *et al.,* 2006: Korajkic *et al.,* 2018; Leight *et al.,* 2018).

Indeed, water that does not meet sanitary standards can affect the performance and health of fish and consequently, the health of consumers (Ntengwe and Edema, 2008; Sule *et al.,* 2016; Olukunle and Oyewumi, 2017). Recent studies, such as those by Ajayi and Okoh (2014) and Mramba and Kahindi (2023), have highlighted the importance of stringent water quality management to limit the spread of contaminants and bacterial pathogens in aquaculture systems.

This study aims to analyze the bacteriological and physicochemical quality of water used in fish farming across three regions of Bechar (Southwestern Algeria): The Boukais fish farming station (CNRDPA), the Taghit fish farm and the Nif Rhaa fish farm in Ouakda, in relation to sanitary standards and to assess potential risks to public health.

MATERIALS AND METHODS

Experimental period

All experiments were conducted over a period of eight months, from January to August 2024, at MTU-Bechar and the CNRDPA-Boukais research center in Bechar, Algeria.

Study area

Three fish farms were studied, located in Boukais, Taghit and Nif Rhaa-Ouakda, situated approximately 50 km, 90 km and 15 km, respectively, from the center of Bechar (Fig 1). These farms are located in arid Saharan environments and are specialized in tilapia farming, particularly Red Tilapia and Nile Tilapia (Fig 2). In Taghit and Nif Rhaa-Ouakda, an integrated aquaculture-agriculture system is practiced, with fish raised in both concrete irrigation water storage ponds and earthen ponds.

Water sampling and analysis

Sampling conditions

The sources of water used in the aquaculture activities are boreholes and shallow wells. Water samples were collected in sterile glass flasks, following the guidelines of ISO 5667-1 (2023) (Fig 3).

All sampling was conducted in the early morning to reduce the influence of temperature fluctuations on water parameters. Samples were then transported in cool boxes and stored at 4°C to preserve their integrity before analysis. The frequency and specific dates of water sampling are provided in Table 1.

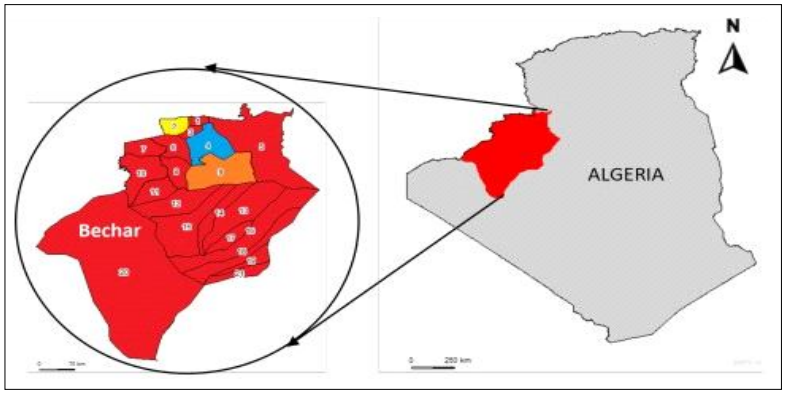
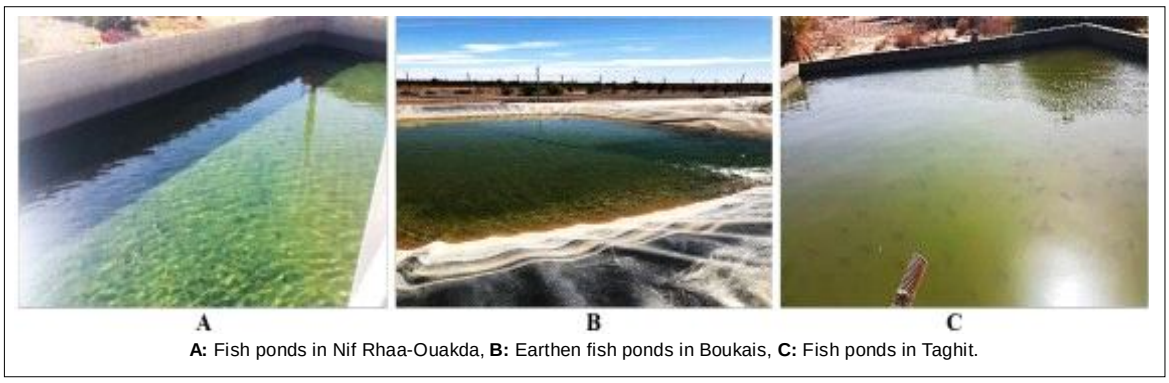


Fig 1: Geographical location of Boukais (in yellow), Taghit (in orange), the center of Bechar (in blue) and the entire territory of Bechar province (in red) (Southwestern Algeria) (GADM, 2024).



A: Fish ponds in Nif Rhaa-Ouakda, **B:** Earthen fish ponds in Boukais, **C:** Fish ponds in Taghit.

Fig 2: Fish ponds in Bechar province (Southwestern Algeria) (Original, 2024)-Photo by E. Benyagoub.

Physicochemical parameters

The physicochemical parameters-pH, temperature, electrical conductivity and total hardness-were analyzed using the standard procedures provided by the APHA and WEF (Lipps *et al.,* 2022).

Bacteriological parameters

Bacteriological analysis was conducted using international standard procedures, as outlined in Table 2.

Interpretation of bacteriological and physicochemical analyses results

The quality of water samples is evaluated by comparing the bacteriological and physicochemical parameters to the established thresholds limits for groundwater and drinking water, as outlined in national regulations (JORA n.18, 2011; JORA n.34, 2011; JORA n.13, 2014) and by the World Health Organization (WHO, 2017).

RESULTS AND DISCUSSION

Physicochemical analysis

The results of the physicochemical analysis of the water supplying the fish ponds are shown in Table 3.

Limited water availability is one of the major challenges to aquaculture development in southern Algeria, a region marked by low rainfall, scarce freshwater resources and heightened susceptibility to climate change (Mramba and Kahindi, 2023). Consequently, experts are focusing on sustainable aquaculture practices in these areas, with an emphasis on water resource planning and management. One approach being explored is the integration of aquaculture with agricultural activities to benefit both sectors (Abbani *et al.,* 2022).

For physicochemical parameters, temperature plays a vital role in aquatic ecosystems, affecting the chemical and physicochemical properties of the water, as well as the organisms inhabiting the pond (Eghomwanre *et al.,* 2019). The recorded average temperatures ranged from 18°C to 21°C, with a minimum of 13°C and a maximum of 29.5°C, variations that are primarily by the season. However, these values meet the requirements of national regulations.

pH is an essential environmental factor that influences the survival, physiology, metabolism and chemical processes of aquatic organisms. It plays a key role in regulating their life cycles and affects the solubility and availability of nutrients. Moreover, pH helps maintain the carbonate and bicarbonate buffering systems, which are vital for the growth and survival of aquatic plants (Eghomwanre *et al.,* 2019; Nair and Nayak, 2023).

The pH results of this study fall within the national regulatory range of 6.0 to 9.0, which is considered optimal for fish production. These findings are consistent with the study by Eghomwanre *et al.* (2019), where 6 out of 10 samples analyzed had pH values ranging from 6.09 to 6.95. Similar results were reported by Ajayi and Okoh (2014), with pH values between 7.82 and 8.15, by Olukunle and Oyewumi (2017), with values ranging from 7.1 to 8.39 and by Mramba and Kahindi (2023), with values ranging from 6.5 to 7.3. It is also consistent with our previous study (Benyagoub, 2023a; Benyagoub, 2024) on the Ouakda groundwater, which is part of the Turonian and Quaternary aquifers (Kabour *et al.,* 2010; Seddiki and Cherif, 2021) with a pH ranging from 7.33 to 8.17, as well as the results of Rezzoug *et al.* (2017), who reported pH values of 7.48 and 7.68. According to Mramba and Kahindi (2023), the pH of pond water should ideally be between 6.5 and 9.5 for effective fish farming. However, certain species may thrive in pH levels between 7.5 and 9, particularly in warmer temperatures (16-27°C), which have been found to be

Table 1: Water sampling frequency.

Samples	Dates of collection
Sb1, Sb2, Sb3	January 28, 2024
Sb4, Sn18, Sn19	February 18, 2024
St11, St12, St13	March 24, 2024
St14, Sb5, Sb6	April 21, 2024
Sb7, Sb8, St15	May 19, 2024
St16, St17, Sb9	June 23, 2024
Sb10, Sn20, Sn21	July 14, 2024

Sb1 to Sb10: Water samples from Boukais, St11 to St17: Water samples from Taghit, Sn18 to Sn21: Water samples from Nif Rhaa-Ouakda.

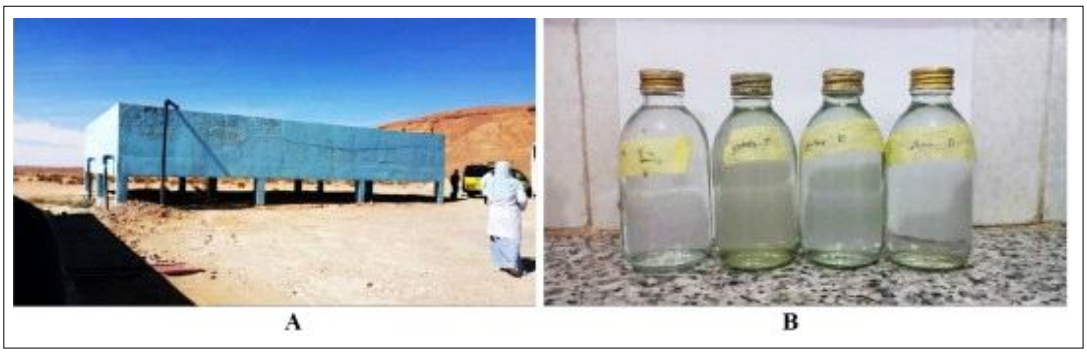


Fig 3: Feed water storage reservoir supplying fish ponds in Boukais (A) and water samples (B) for analysis (Original, 2024)-Photo by E. Benyagoub.

conducive to tilapia productivity in small ponds (Ntengwe and Edema, 2008).

The electrical conductivity (EC) results for the Taghit and Nif Rhaa-Ouakda samples fall within the national regulatory limits and are consistent with the findings of our previous study (Benyagoub, 2023a), with EC values ranging from 973 to 1130 µS/cm. However, the Boukais samples exhibit higher EC due to increased total hardness (TH) values, which are also related to the pH of the medium. The TH and EC results are higher than those reported by Ajayi and Okoh (2014), Olukunle and Oyewumi (2017) and Eghomwanre *et al.* (2019). This may be due to the lithological characteristics of Quaternary limestone, where the calcium and magnesium ions contributing to hardness are released through the hydrolysis of silicate minerals found in the soil (Nabbou *et al.,* 2020; Benyagoub, 2023a). Rezzoug *et al.* (2017) highlight that the soils and groundwater in the studied areas are at risk of salinization, primarily due to the high salinity of irrigation water, a consequence of the declining water table. This salt buildup worsens during the hot summer months.

Despite the EC, TH and pH values observed in this study, *Oreochromis niloticus* can thrive in waters with a salinity close to 11.5g/L and a pH range of 8 to 11. It can reproduce continuously every 15 days at temperatures above 23°C (Amoussou *et al.,* 2016), from March to September in the studied areas known for their hot climate. However, salinity levels exceeding 16 ppt can reduce food intake and feed conversion efficiency, redirecting more energy toward maintaining homeostasis rather than supporting growth (Mramba and Kahindi, 2023). Although the current study did not conduct a heavy metals assessment due to the lack of analytical tools, a study by Barszcz *et al.* (2024) shows that recirculating aquaculture systems contribute to higher levels of heavy metal bioaccumulation in fish meat compared to flow-through systems. It is important to note that, according to Barszcz *et al.* (2024), the levels detected in the tested trout muscle samples were low and did not exceed the maximum permissible limits defined by the EU and these results were not derived from the present study.

This highlights the importance of water management technologies in aquaculture and their impact on food safety related to fish meat consumption.

Bacteriological analysis

The results of the bacteriological analysis of the water supplying the fish ponds are shown in Table 4 and Fig 4.

Given the importance of physicochemical parameters such as temperature, pH, dissolved oxygen (DO), ammonia

Table 2: Bacteriological analysis protocols.

Bacterial parameters	Culture media and technique of isolation	Incubation	References
Total aerobic mesophilic flora	TGEA	22°C for 72 hours	ISO 6222 (1999)
Fecal streptococci	Rothe broth and Litsky broth using MPN method	37°C for 24 to 48 hours	NF EN ISO 7899-1 (1999)
Coliforms	MacConkey agar using membrane filter technique	30 and 44°C for TC and FC, respectively, for 24 to 48 hours	NF V08-050 (2009)
SRC	Meat-liver agar incubated under anaerobic conditions using culture tube	46°C for 24 to 48 hours	NF T 90-415 (1985)
Salmonella spp	SS agar using membrane filter technique	37°C for 24 hours	Health protection agency (HPA, 2004)
Pseudomonas spp	Cetrimide agar using membrane filter technique	37°C for 24 hours	ISO 16266 (2006)

MPN: Most probable number; SRC: Sulfite-reducing *Clostridia*; TGEA: Tryptone glucose yeast extract agar; SS agar: *Salmonella-Shigella* agar; FC: Fecal coliforms; TC: Total coliforms.

Table 3: Physicochemical analysis results of the water supplying fish ponds.

PP (Mean value ± SD) / WS	T (°C)	pH	EC (µS/cm)	TH (mg/L)
Sb1 to Sb10 (Boukais)	18.51±5.28	8.531±0.163	3848±188.33	873.9±173.48
St11 to St17 (Taghit)	21.18±7.93	7.631±0.252	1802±913.67	339.62±65.74
Sn18 to Sn21 (Nif Rhaa-Ouakda)	18.85±4.59	7.405±0.413	1313±438.40	297.74±32.76
Algerian standard	15-25	6.5-9	2800	200

PP: Physicochemical parameters; WS: Water samples; SD: Standard deviation; T (°C): Temperature; EC: Electrical conductivity; TH: Total hardness; Sb1 to Sb10: Water samples from Boukais; St11 to St17: Water samples from Taghit; Sn18 to Sn21: Water samples from Nif Rhaa-Ouakda. Source: Own study.

and water clarity, the bacteriological quality of water is also a critical parameter in the aquaculture ecosystem, making it more vulnerable to disease (Mramba and Kahindi, 2023).

The borehole water used for tilapia farming in Nif Rhaa and Boukais demonstrated good microbiological quality. In contrast, the shallow well water from Taghit (3 out of 7 samples) and the reservoir water at the Boukais aquaculture station exhibited poor quality, with contamination by coliforms, *Salmonella* spp. and *Pseudomonas* spp., varying from one sample to another. In the Boukais reservoirs (Sb6 to Sb10), this contamination is probably attributed to the integration of recycled water-treated by sedimentation and filtration-into an elevated storage tank at a 30:70 ratio with fresh water.

The results of the TAMF load, coliforms and fecal streptococci from the eight contaminated samples (Sb6, Sb7, Sb8, Sb9, Sb10, St15, St16 and St17) were found to be lower than the bacterial loads reported by Ajayi and Okoh (2014); Sule *et al.* (2016); Eghomwanre *et al.* (2019) and Adebami *et al.* (2020).

Contamination by coliforms and streptococci in water samples could result from increased microbial infiltration, possibly due to fecal contamination of either animal or human origin, improper placement of the storage reservoir, insufficient treatment of the feed water storage reservoir to eliminate microorganisms, or inadequate cleaning frequency of the reservoir (Ajayi and Okoh, 2014; Benyagoub, 2023a).

The microbial load already present in contaminated water may be further increased by the use of animal manure, a practice sometimes used to enhance fish growth. This organic input not only enriches the pond environment with nutrients but also increases concentrations of ammonia and organic nitrogen, creating favorable conditions for the proliferation of various microorganisms (Njoku *et al.,* 2015; Sule *et al.,* 2016; Rathod *et al.,* 2023). However, neglecting proper fishpond management practices (Ajayi and Okoh, 2014; Opiyo *et al.,* 2018) could pose a health risk to the fish by facilitating the transmission of potential pathogens, which could subsequently affect human health (Sule *et al.,* 2016). Aquaculture's success is closely tied to a healthy aquatic environment (Cretu *et al.,* 2016). Several studies have shown

Table 4: Bacteriological analysis results of the water supplying fish ponds.

WS	TAMF at 22°C (n Log_{10} CFU/mL)	Coliforms (CFU/100 mL)		F. Strep. (MPN/100 mL)	SRC (spore/20 mL)	*Salmonella* spp. (per 250 mL)	*Pseudomonas* spp. (per 250 mL)
		TC	FC				
Sb1	2.28	1	<1	<1	<1	-ve	-ve
Sb2	2.38	4	<1	<1	<1	-ve	-ve
Sb3	2.05	<1	<1	<1	<1	-ve	-ve
Sb4	1.41	<1	<1	<1	<1	-ve	-ve
Sb5	2.25	2	<1	<1	<1	-ve	-ve
Sb6	2.84	12	7	<1	2	-ve	-ve
Sb7	4.0	70	19	2	10	+ve	+ve
Sb8	3.46	19	3	0.7	8	-ve	+ve
Sb9	2.76	5	3	<1	4	-ve	-ve
Sb10	3.34	25	6	0.7	2	-ve	-ve
St11	2.62	10	<1	<1	<1	-ve	-ve
St12	2.53	10	<1	<1	<1	-ve	-ve
St13	2.27	2	<1	<1	<1	-ve	-ve
St14	2.0	<1	<1	<1	<1	-ve	-ve
St15	4	40	10	0.7	10	-ve	+ve
St16	3.5	30	7	0.4	5	-ve	+ve
St17	3	25	5	0.4	6	-ve	+ve
Sn18	0.78	<1	<1	<1	<1	-ve	-ve
Sn19	2.11	10	<1	<1	<1	-ve	-ve
Sn20	2.4	8	<1	<1	<1	-ve	-ve
Sn21	2.04	<1	<1	<1	<1	-ve	-ve
Alg. standard	/	10	<1	<1	<1	Abs	Abs
WHO (2017)	2	<1	<1	<1	0	/	Abs

WS: Water samples, Sb1 to Sb5: Boukais borehole water samples, Sb6 to Sb10: Elevated water storage tank, St: Water samples from shallow wells in Taghit, Sn: Water samples from Nif Rhaa-Ouakda, TAMF: Total aerobic mesophilic flora, F. Strep.: Fecal streptococci, SRC: Sulfite-reducing *Clostridia*; CFU: Colony-forming unit, TC: Total coliforms, FC: Fecal coliforms, Alg. standard: Algerian standard for drinking water, WHO (2017): World Health Organization guidelines for drinking water, Abs: Absence of bacterial pathogen, +ve: Positive culture; -ve: Negative culture. Source: Own study.

that poor water quality poses a significant threat to both fisheries and fish population restoration by inducing stress in fish and increasing their susceptibility to opportunistic pathogens (Nair and Nayak, 2023; Mramba and Kahindi, 2023; Guetarni and Labdi, 2023). Sule *et al.* (2016) recommend monitoring the frequency of water changes, especially in concrete ponds, as this can significantly influence the microbial load.

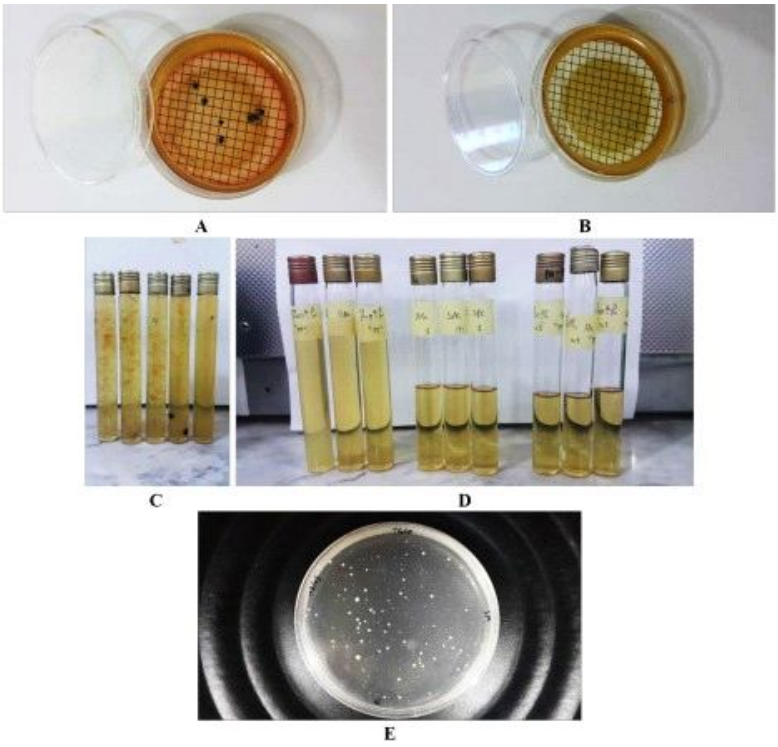
To mitigate these risks, several methods-including well construction and rehabilitation, the use of filters such as zeolite/bentonite-based ceramic filter membranes, storage tank cleaning, chlorine disinfection and proper drinking water handling practices-can improve water quality and reduce waterborne diseases that may affect fish and, consequently, consumer health (Benyagoub, 2023a; Djana *et al.,* 2024).

Identification of potential pathogenic bacteria

The results of the identification of potential pathogenic bacteria in the water that supplies the fish ponds are presented in Table 5.

The identification of pathogenic species revealed the presence of *Salmonella choleraesuis* ssp. *arizonae* in sample Sb8 and *Pseudomonas aeruginosa* as an opportunistic pathogen in five samples (Sb7, Sb8, St15, St16, St17).

These findings support the research conducted by Ntengwe and Edema (2008); Ajayi and Okoh (2014); Njoku *et al.* (2015); Eghomwanre *et al.* (2019) and Adebami *et al.* (2020), who examined fish pond waters in Zambia, Ondo State, the Niger Delta, Edo State and Lagos (Nigeria),



(A): *Salmonella* spp on SS agar, (B): *Pseudomonas* spp on Cetrimide agar, (C): Sulfite-reducing *Clostridia* on Meat liver agar, (D): Search for fecal streptococci using Rothe broth, (E): TAMF on TGEA medium.

Fig 4: Bacteriological analysis of water samples (Original, 2024)-Photo by E. Benyagoub.

Table 5: Results of pathogenic bacteria identification isolated from water supplying fish ponds in Bechar province.

WS	*Salmonella* spp.	*Pseudomonas* spp.
Sb7	-ve (*E. coli, Enterobacter cloacae, Aeromonas hydrophila, Klebsiella oxycota*)	
Sb8	*Salmonella choleraesuis* ssp. *arizonae*	+ve (*Pseudomonas aeruginosa*)
St15	-ve (*Aeromonas hydrophila, Enterobacter amnigenus*)	
St16	-ve (*Vibrio fluvialis*, *Aeromonas hydrophila*)	
St17	-ve (*Aeromonas hydrophila*)	

WS: Water samples; Sb7 and Sb8: Water samples from the elevated water storage tanks at Boukais; St: Water samples from shallow wells in Taghit; +ve: Positive culture; -ve: Negative culture. Source: Own study.

respectively. Their investigations revealed a wide variety of bacterial species present in the pond waters, including, but not limited to, *Staphylococcus* spp., *Streptococcus* spp., *Micrococcus* spp., *Bacillus* spp., *Aeromonas* spp., *Pseudomonas* spp., *E. coli*, *Enterobacter* spp., *Proteus* spp., *Salmonella* spp., *Citrobacter* spp. and *Serratia* spp. As noted by Sule *et al.* (2016), several bacterial infections, particularly those caused by *Aeromonas* spp. and *Pseudomonas* spp., are common in fish ponds. The findings of this study are also supported by our previous research on water stored in concrete reservoirs in Nif Rhaa-Ouakda, from which the following bacterial species were isolated: *Escherichia coli, Aeromonas hydrophila, Chromobacterium violaceum, Escherichia vulneris, Enterobacter cloacae* and *Enterobacter amnigenus* (Benyagoub, 2023a; Benyagoub, 2023b; Benyagoub, 2024).

The presence of bacterial species such as *Pseudomonas*, *Streptococcus* and other pathogens, including fungal and parasitic species, in the water indicates contamination. This contamination contributes to the transmission of infections and can negatively affect the growth and survival of fish in pond ecosystems (Ajayi and Okoh, 2014; Opiyo *et al.,* 2018; Adebami *et al.,* 2020; Mramba and Kahindi, 2023).

The studies by Njoku *et al.* (2015) and Mramba and Kahindi (2023) explored the relationship between pond water parameters, fish yield and the potential for disease outbreaks. They found that microbial contamination could reduce fish yield, contribute to disease outbreaks and result in economic losses. Additionally, it poses a risk to consumers, especially if the harvested fish are not properly processed.

CONCLUSION

The analyzed samples exhibited significant salinity, as evidenced by high hardness and electrical conductivity, particularly in the Boukais samples. These properties are favorable for tilapia farming in the Saharan environment. However, due to the unavailability of appropriate equipment, other physicochemical parameters-especially heavy metal content-were not measured. It is recommended that future studies address this limitation.

Although the majority of the water samples analyzed (62%) comply with national regulations, contamination by fecal coliforms, fecal streptococci and potentially pathogenic or opportunistic species such as *Pseudomonas* spp and *Salmonella* spp., was detected in 38% of the samples, specifically from tank storage water in Boukais and shallow well water in Taghit

These results highlight the importance of strengthening water quality management and implementing effective fish pond management practices. Special attention should be given to the reservoirs that supply the fish ponds, to ensure a safe environment for fish farming, guarantee food security, reduce disease outbreaks and ultimately protect public health.

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Disclaimers

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Informed consent

Not applicable.

Conflict of interest

The authors declare that they have no conflicts of interest. No financial support was received for this research.

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