Evaluating water Disinfection Practices with Emphasis on UV-Based Alternatives for Legionella Control in ALRUSTAQ Hospital Water System

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Introduction

Legionella are opportunistic pathogens in water systems, forming biofilms that pose health risks, especially to immunocompromised individuals (Nisar et al., 2020; Hunter et al., 2021).
Early detection through DFA, PCR, and urine antigen testing is crucial (Plummer & Pavia, 2020).
Disinfection methods, such as copper-silver ionization and UV irradiation, have variable efficacy and environmental concerns (Carlson et al., 2020).
This study investigates a sustainable, chemical-free photochemical approach to eliminate Legionella biofilms, improving hospital water safety.

Aim and Objectives

Aim:
To evaluate various disinfection methods and developing eco-friendly solution for controlling Legionella DNA in AL RUSTAQ hospital water systems by using Photochemistry.

Objectives:
I. To analyze methods of taking Legionella biofilm samples
II. To identify the diagnosis methods of Legionella antigen on human health
III. To evaluate the water disinfection methods and applying photochemistry techniques as a green alternative.

Litrature Review

Water and swab samples from hospital taps and cooling towers were analyzed for Legionella DNA using PCR (Deiana et al.., 2021; Wise et al., 2021). Legionella thrives in hospital systems, particularly between 30-40°C (Mavridou et al., 2008; Abdul Samad et al., 2004).

Diagnosis relies on symptoms like pneumonia and fever, with methods including DFA, serological tests, urine antigen tests, and PCR for rapid detection (Gattuso et al., 2022).

Disinfection strategies such as copper-silver ionization (Carlson et al., 2020), high-temperature treatment (Chen et al., 2005), and UV light are used, but each has limitations. Photochemistry and photocatalysis offer an eco-friendly alternative with potential for greener solutions (Berruti et al., 2022).

Methodology

Lab Experiment

Was conducted at AL Yaqeen School using UV light, methylene blue, biochar, and hydrogen peroxide to test photochemical disinfection effectiveness.

Materials Used

- Methylene Blue Dye (20 mg/L): Simulates presence of Legionella DNA
- Biochar (LDH) – 10 mg: Acts as a photocatalyst
- Hydrogen Peroxide (H_2O_2) – 5 mL, 1%: Oxidizing agent

Devices Used

- UV Lamp (394 nm): Provides light energy for the photochemical reaction
- Centrifuge: Separates particles from solution before measurement
- PCR Device: Measures pollutant concentration (used here as a spectrophotometer to quantify dye reduction)

Quantitative Analysis

A questionnaire was distributed to Omani water disinfection companies and OWTACO staff at Al Rustaq Hospital to assess current disinfection methods, their effectiveness, safety, and environmental impact. It also explored interest in sustainable alternatives like photochemical disinfection, along with economic and operational challenges and willingness to adopt new solutions.

Qualitative Analysis

Interviews with doctors and nurses at AL Rustaq Hospital provided insights into Legionella infection, diagnostics, and treatments.

Results & Discussion

Experiment Results

Time (min)	Pollutant concentration (ppm)	Percentage Degradation (%)
0	20.30	0
5	12.35	39.15
10	10.86	46.49
15	7.90	61.09
20	5.75	71.70
35	2.20	89.17

Table (1): Degradation of Methylene Blue Over Time

Table (1) shows the results of the experiment demonstrated a significant reduction in methylene blue concentration, confirming the effectiveness of the photocatalytic method. UV radiation activated hydrogen peroxide and the catalyst, enhancing degradation. Hydrogen peroxide was chosen for its safe breakdown into water and oxygen, avoiding harmful by-products. The catalyst was regenerated after each cycle, ensuring sustainability.

Figure (1) Shows a Centrifuge Device

A methylene blue solution was treated with biochar and hydrogen peroxide, then irradiated with UV light; samples were taken every 5 minutes, centrifuged, and analyzed using a PCR device to monitor pollutant reduction.

Survey Results

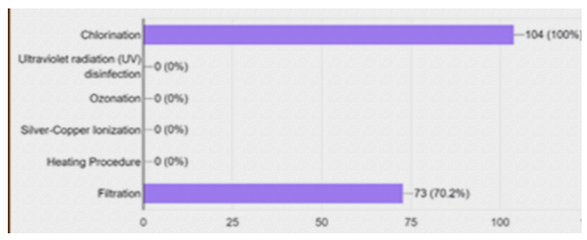

Figure (2) Water disinfection methods are currently used in companies

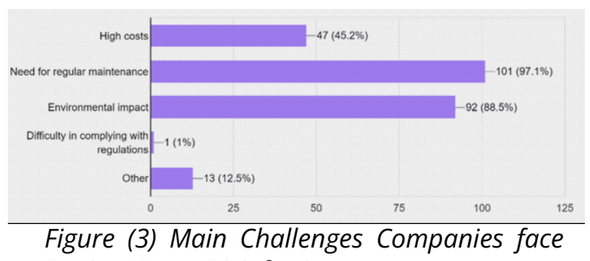

Figure (3) Main Challenges Companies face During Water Disinfection

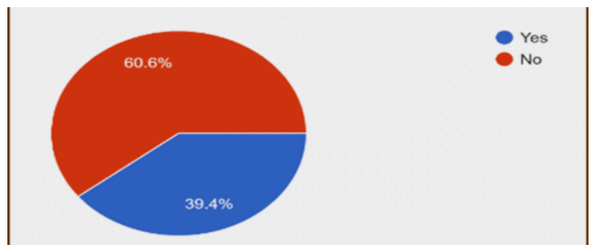

Figure (4) Awareness of Photochemical Effectiveness for Water Disinfection

The survey results show that all participants use chlorine as the primary disinfection method, reflecting its perceived effectiveness. Additionally, 70.2% also use filtration to enhance water quality by reducing impurities and harmful by-products. However, 97.1% reported challenges with regular maintenance, and 88.5% expressed concerns about chlorine's environmental impact. Furthermore, 45.2% highlighted high costs due to pipe corrosion. Despite these issues, only 39.4% are aware of photochemical disinfection, indicating a need to raise awareness of eco-friendly alternatives.

Interview

Interviews with Rustaq Hospital medical staff revealed that Legionella bacteria naturally inhabit freshwater but become harmful when they multiply in man-made water systems like cooling towers and plumbing. The bacteria spread through inhaled contaminated water droplets, causing Legionnaires' disease severe pneumonia with symptoms such as cough, fever, and shortness of breath. Diagnosis relies on clinical tests, including lab analysis and chest X-rays. Treatment involves antibiotics (amoxiclav, clarithromycin) and supportive care like breathing exercises and chest physiotherapy. In severe cases, surgery may be needed. This highlights the importance of controlling water systems to prevent bacterial growth and infection.

Conclusion

Although chlorine remains the predominant method for water disinfection in Oman, its well-documented health, environmental, and maintenance concerns raise significant challenges. Laboratory experiments demonstrated that UV disinfection, when combined with photocatalytic LDH and hydrogen peroxide, resulted in a 90% reduction in Legionella-like bacteria. Interviews with healthcare professionals further emphasized the clinical risks associated with Legionella infections. These findings highlight the viability of UV-based photochemical disinfection as a more effective, environmentally sustainable, and safer alternative to chlorine.

Recommendations

- Use eco-friendly disinfection like UV light and hydrogen peroxide to cut chlorine use.
- Educate healthcare workers on Legionella detection and treatment.
- Invest in research for safer, sustainable disinfection technologies.

References

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