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# Assessment of Water Quality and Fungal Contamination in Hospital Wastewater from Erbil City, Iraq

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**Abstract**

The present study focused on the wastewater from three hospitals in Erbil: Hawler Teaching Hospital, Rezgary Teaching Hospital, and Rozhawa Emergency Hospital. Wastewater samples were collected monthly (December 2024 to February 2025) for some parameters related to water quality, fungal counts, and detections. The study aims to determine the risk of hospital wastewater in terms of contaminated disposal water and to investigate the types of fungi present in it. The results showed that wastewater was characterized by neutral to slightly alkaline. Electrical conductivity (EC) and biochemical oxygen demand ($BOD_5$) values were high and exceeded local and international discharge guidelines. Related to nutrient content, both phosphate ($PO_4$) and nitrate ($NO_3$) were high in all sampling sites. A total of 13 fungal genera were identified, suggesting that hospital wastewater provides a conducive environment for fungal growth. The highest number of fungi and the most isolates were detected at Razgary Teaching Hospital, where 8300 ($CFU/mL^{-1}$) and 16 species of fungi were identified out of a total of 19 species, coinciding with the highest temperature and lowest phosphate concentration compared to other hospitals. The most common fungal species detected in all studied hospitals were: *Aspergillus niger*, *Candida albicans*, *Geotrichum candidum*, *Mucor* sp., and *Penicillium* sp. The results highlighted that the risk of polluted hospital wastewater poses a threat to both public health and the environment. Therefore, it is necessary to build sewage treatment units and monitor the quality of the discharged water.

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## 1. Introduction

Medical wastewater (MWW) is a critical environmental concern, significantly different from wastewater released by other sources, and is both harmful and infectious. The effluent is released from surgical rooms, diagnostic laboratories, radiology departments, and infectious wards [1]. Comprises pathogenic microbes, harmful organic pollutants, radioactive substances, and medicinal chemicals. Nonetheless, the MWW is an optimal medium for a diverse array of microorganisms, particularly bacteria, viruses, fungi, and parasites [2]. The abundance of several pathogenic fungi in MWW emphasizes the potential public health risk associated with MWW discharge into receiving waters [3]. The population growth, accelerated urbanization, and expansion of healthcare facilities have resulted in a notable increase in hospital wastewater production [4]. In developed countries, healthcare facilities generate an average of 400–1,200 liters of wastewater per bed per day, whereas in developing countries, the wastewater generation is 200–400 liters per person per day [5]. In many countries, MWW is dumped directly into sewage systems without any additional treatment. If untreated, the pathogens in the MWW persist in soil or water for extended periods, entering the food chain and creating infectious diseases and health concerns to humans [6]. Additionally, fungi capable of rapid growth and dispersing their spores into the external environment pose a significant threat to human health and the environment. In comparison to other microorganisms, fungi have simpler nutritional requirements and a greater capacity to grow at low water activity [7]. The prevalence of fungi in hospital and clinical settings is attributed to environmental factors such as temperature, moisture, and nutrients, which create conducive conditions for the proliferation of fungal species in healthcare waste [8]. Fungal infections can range from moderate to lethal, depending on the infection site and the individual's immune system [9]. Fungi have been associated with several illnesses, including allergies, respiratory diseases, skin infections, and life-threatening meningitis [10]. Nonetheless, limited studies have identified fungal populations in MWW. Therefore, the present study aims to determine the level of fungal contamination and identify harmful fungi in wastewater from hospitals in Erbil city.

## 2. Materials and Methods

### 2.1. Study Area and Sample Collection

Hospital wastewater samples for physico-chemical and fungal analysis were collected from three hospitals in Erbil city: Hawler Teaching Hospital, Rzgary Teaching Hospital, and Rozhawa Emergency Hospital. Samples were collected from December 2024 to February 2025, with three frequencies for each hospital. The samples were stored in sterile bottles with lids labeled with the sample number, hospital names, and the collection date. The samples were subsequently transported to the laboratory for counting and identification of fungi.

### 2.2. Physicochemical Analysis

Some physical and chemical tests of MWW were conducted directly in the field and laboratory after the samples were brought to the laboratory. A mercury thermometer is used to measure water temperature; a pH meter is used to measure pH; and an EC meter is used to measure electrical conductivity. Dissolved oxygen and $BOD_5$ were tested using the Azide modification of the Winkler method. Meanwhile, phosphate was determined using the ascorbic acid method, and nitrate using the ultraviolet spectrophotometric method [11].

### 2.3. Fungal Counting and Isolation Techniques

The pour plate method was applied as described by Wehr and Frank [12], using Potato Dextrose agar as a cultivated medium. The plate was incubated at 25±0.5°C for five days. Results expressed as $CFU/mL^{-1}$.

### 2.4. Identification of Fungi

The isolated fungus was subsequently identified using cultural and morphological characteristics, such as pigmentation, conidial morphology, and colony development pattern. A smear prepared with lactophenol cotton blue stain was also employed to identify the fungus. Consequently, the VITEK 2 COMPACT system or instrument was employed to identify clinically significant yeasts.

### 2.5. Statistical Analysis:

One-way analysis of variance (ANOVA) was used to compare physicochemical factors and fungal counts statistically. Multiple comparisons were examined using the Duncan test. A Pearson correlation test approach was used to assess the significance of the relationship. The SPSS version 25 software and Microsoft Office Excel 2010 were used for all statistical and mathematical calculations.

## 3. Results and Discussion

### 3.1. Temperature

Table 1 presents the physicochemical variables and fungal counts for the wastewater from the three studied Erbil hospitals from December 2024 to February 2025. The wastewater temperatures ranged from 11 °C to 39 °C. Rezgary Teaching Hospital recorded the highest temperature during February. Statistically significant differences ($P \leq 0.05$) were found with other hospitals, which may be a result of heat-intensive hospital operations such as autoclaving or laundry. The lowest temperature observed in Rozhawa Emergency Hospital (11°C) indicates minimal thermal discharge, which may be attributed to various operational or infrastructure features. Fungal metabolism, solubility of oxygen, and other gases in wastewater are greatly affected by water temperature [13].

### 3.2. pH

One of the most essential indicators of water quality and the degree of pollution in a body of water is the pH value of the water system [14]. The pH of the wastewater varied from 7.13 to 8.69, with most values ranging between neutral and slightly alkaline. The highest pH values characterize the Rozhawa Emergency Hospital due to residual supplies or medications. A higher pH may influence the survival and composition of fungal communities because most fungal species prefer conditions that are near neutral or slightly acidic [15].

**Table 1.** Physicochemical and fungal numbers for Erbil hospitals' wastewater.

| Studied factors | Hawler Teaching Hospital | | | Rezgary Teaching Hospital | | | Rozhawa Emergency Hospital | | |
|---|---|---|---|---|---|---|---|---|---|
| | December | January | February | December | January | February | December | January | February |
| Water Temp.ºC | 20 | 17 | 14 | 28 | 32 | 39 | 14 | 13 | 11 |
| pH | 7.35 | 7.21 | 7.13 | 7.69 | 7.4 | 7.48 | 8.69 | 8.27 | 7.84 |
| EC (µS.cm$^{-1}$) | 2004 | 1129 | 1082 | 806 | 611 | 609 | 3274 | 2247 | 1749 |
| $BOD_5$ (mg.l$^{-1}$) | 484.84 | 363.63 | 424.24 | 303.03 | 363.63 | 181.81 | 363.63 | 348.48 | 303.03 |
| $NO_3$ (mg.l$^{-1}$) | 313.25 | 275.02 | 311.24 | 316.46 | 295.18 | 219.27 | 337.75 | 325.3 | 312.04 |
| $PO_4$ (mg.l$^{-1}$) | 406.5 | 331 | 265 | 57 | 78.5 | 69 | 378.51 | 317.49 | 391.5 |
| Fungal Count (CFU.ml$^{-1}$) | 2500 | 4100 | 6550 | 8300 | 7050 | 4600 | 4100 | 3450 | 3050 |

**3.3. Electrical Conductivity (EC)**

The ability of water to conduct an electrical current is measured by its electrical conductivity (EC). The ability results from the ions that are present in water [16]. As a result of variations in ionic concentrations, the electrical conductivity values varied significantly between hospitals. The highest EC (3274 µS/cm) was recorded at Rozhawa Emergency Hospital wastewater in December; this could be attributed to the presence of pharmaceutical residues, dissolved salts, or surfactants. In contrast, the lowest conductivity (609 µS/cm) was observed in the wastewater of Rezgary Hospital, which might indicate a lower pollution load.

**3.4. Biochemical Oxygen Demand ($BOD_5$)**

$BOD_5$ is an essential indicator of organic load and water quality. The maximum $BOD_5$ value was recorded at Hawler Teaching Hospital in December, ranging from 181.81 to 484.84 mg/L. High organic loads, accompanied by reduced oxygen levels in receiving water bodies, threaten aquatic life, coinciding with these high numbers. Significantly, all recorded $BOD_5$ values exceed the WHO-recommended limit of less than 50 mg/L for treated hospital effluents, suggesting either inadequate treatment or excessive pollution inputs [17].

**3.5. Nitrate ($NO_3^-$)**

Nitrate plays an important role as a nutrient element for fungal metabolism and as an indicator of water quality. Hospital wastewater is characterized by a high nitrate content, ranging from 219.3 to 337.7 mg/L, which may be due to contamination from urea, medications, and feces. Both nitrate and phosphate are primary causes of eutrophication in water ecosystems and water resource contamination. Contamination of drinking water with nitrate poses a high risk for infants through the incidence of methemoglobinemia [18].

**3.6. Phosphate ($PO_4^{3-}$)**

The highest phosphate concentration was observed in Hawler Teaching Hospital, reaching 406.5 mg/L. That exceeds effluent discharge standards for local and international guidelines. While the lowest content was recorded in Rizgary Teaching Hospital (57 mg/L), with statistically significant differences ($P \leq 0.05$) from other studied hospitals. These higher phosphate levels in wastewater probably come from the continuous application of detergents and disinfectants in hospitals [19].

**3.7. Fungal Load (CFU/mL)**

The wastewater of Rizgary Teaching Hospital contains the highest levels of fungal count, with 8300 CFU/ml recorded in December. However, the other two studied wastewater samples also showed a high fungal count, with statistically insignificant differences ($P > 0.05$) among them. Hospital wastewater can contain pathogenic fungi that pose a risk to human health. This may be attributed to the high organic and nutrient load in wastewater, with a lack of wastewater treatment units in the Hospital, which promotes fungal growth [20].

**3.8. Interpretation of correlation parameters**

From Pearson correlation analysis, several significant correlations at the 0.05 and 0.01 levels are revealed between physicochemical and fungal count variables of wastewater samples from hospitals in Erbil, as shown in Table 2. These relationships provide essential information for developing efficient wastewater treatment plants and assessing any water quality risks to humans and the environment.

There is a significant positive correlation ($r=0.791$, $P \leq 0.05$) between water temperature and EC of wastewater. This may be related to the higher temperature, increased ion concentration and solubility, which is a well-known phenomenon in water chemistry. While water temperature has a significant negative correlation ($r = -0.862$, $P \leq 0.05$) with the phosphate of hospital wastewater, this indicates that the phosphate content tends to decrease with increasing water temperature, which may be related to improved microbial assimilation or temperature-driven changes in nutrient solubility.

On the other hand, wastewater electrical conductivity exhibits a significant positive correlation with both phosphate ($r = 0.767$, $P \leq 0.05$) and nitrate ($r = 0.654$), indicating that an increase in nutrient content is associated with a higher ionic value in hospital wastewater. This may be attributed to hospital effluent releasing nutrient-rich materials like pharmaceuticals, human feces, and cleaning agents. However, a moderately significant positive correlation was found between nitrate and $BOD_5$ ($r = 0.628$), indicating a known relationship between organic matter content and nutritional enrichment. Laboratory effluent and human feces probably affect both variables.

Conversely, phosphate content and fungal density have a significant negative correlation between them ($r=-0.794$, $P\leq0.05$), suggesting that high phosphate content inhibits fungal growth. Shekha [21] found the same phenomenon, suggesting that high phosphate levels may be behind the inhibition of microorganisms. High phosphate content in aquatic ecosystems may also cause the medium's pH to shift into an alkaline range, creating unfavorable conditions for fungal growth.

**Table 2.** Pearson correlation coefficients (r) were calculated for Erbil hospitals' wastewater.

| Wastewater parameters | Water Temperature | pH | EC | $BOD_5$ | $NO_3$ | $PO_4$ |
|---|---|---|---|---|---|---|
| pH | -0.343 | 1 | | | | |
| EC | -0.678* | 0.791* | 1 | | | |
| $BOD_5$ | -0.532 | -0.163 | 0.354 | 1 | | |
| $NO_3$ | -0.710* | 0.506 | 0.654 | 0.628 | 1 | |
| $PO_4$ | -0.862** | 0.292 | 0.767* | 0.562 | 0.502 | 1 |
| Fungi | 0.460 | -0.269 | -0.603 | -0.160 | -0.022 | -0.794* |

*Correlation is significant at 0.05 levels **Correlation is significant at 0.01 levels.

**3.9. Detection and identification of fungi**

Hospital wastewater consists of a complex of chemicals and biological effluent that poses a serious risk to human health and the environment. Fungi in hospital wastewater are a dangerous component that deserves careful attention. As shown in Table 3 and Figure 1, several fungal genera, including *Alternaria*, *Aspergillus*, *Candida*, *Cladosporium*, *Fusarium*, *Geotrichum*, *Humicola*, *Mucor*, *Paecilomyces*, *Penicillium*, *Rhodotorula*, *Trichophyton*, and *Trichosporon*, have been identified. This suggests not only the lack of wastewater treatment plants in these hospitals but also the possibility of opportunistic fungi spreading in the environment due to their suitability. High loads of ionic and organic content, such as increases in EC and $BOD_5$ levels, create a suitable environment for fungal growth by stimulating fungal metabolism and survival, leading to the production of the highest fungal count in wastewater samples [22].

**Table 3.** Isolated fungi from the wastewater of Erbil hospitals.

| Fungal species | Hawler Teaching Hospital | Rezgary Teaching Hospital | Rozhawa Emergency Hospital |
|---|---|---|---|
| *Alternaria* sp. | − | + | + |
| *Aspergillus flavus* | − | + | + |
| *Aspergillus fumigatus* | + | + | − |
| *Aspergillus niger* | + | + | + |
| *Candida albicans* | + | + | + |
| *Candida inconspicua* | + | − | − |
| *Cladosporium* sp. | − | + | + |
| *Fusarium* sp. | + | + | − |
| *Geotrichum candidum* | + | + | + |
| *Geotrichum klebahnii* | − | + | + |
| *Humicola* sp. | − | + | + |
| *Mucor* sp. | + | + | + |
| *Mycelia sterilia* | + | − | + |
| *Paecilomyces* sp. | + | − | + |
| *Penicillium* spp. | + | + | + |
| *Rhodotorula* sp. | − | + | − |
| *Trichophyton* spp. | − | + | + |
| *Trichosporon inkin* | + | + | − |
| *Trichosporon asahii* | + | + | − |

Note: + detected, - not detected

The wastewater from both Hawler and Rozhawa hospitals contains high levels of nitrate and phosphate nutrients, which provide essential elements that promote and support fungal growth. Furthermore, the neutral to slightly alkaline pH levels contribute to the survival of fungi such as *Aspergillus* and *Penicillium* [23].

Fungi are highly adaptable organisms capable of surviving in harsh and nutrient-variable environments. This resilience is attributed to their ability to produce biofilms, resist antimicrobial agents, and form resilient spores [24]. The presence of live and resistant fungi in hospital wastewater environments and their continuous discharge often originates from clinical wards, surgical areas, and laboratories. When released into wastewater or natural water bodies, these fungi can act as vectors for antifungal resistance and reservoirs of infection, posing risks to human health and the environment over time [25].

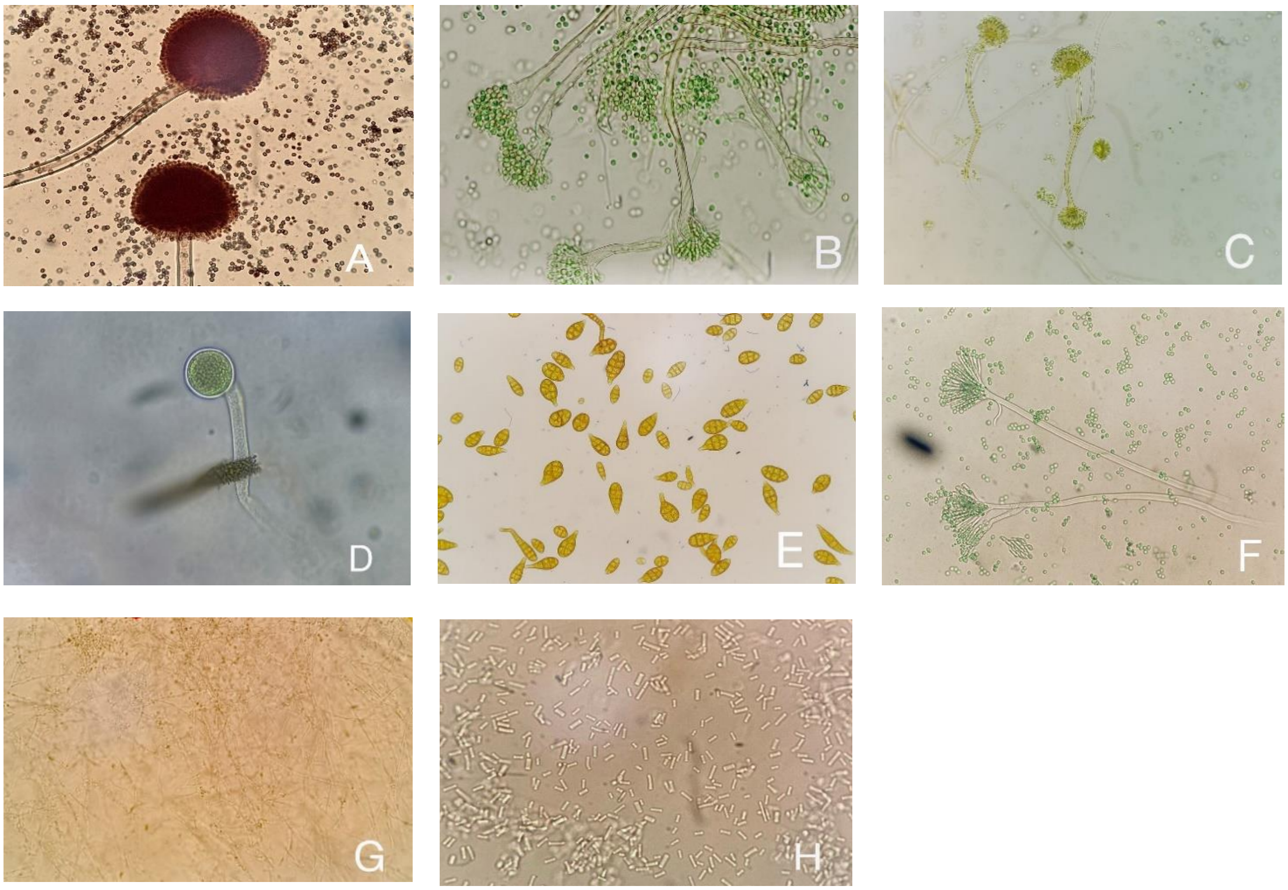


**Figure 1.** Microscopic images of fungi species identified (40X) in the MWW. These are (A) *Aspergillus niger*, (B) *Aspergillus fumigates*, (C) *Aspergillus flavus*, (D) *Mucor* sp., (E) *Alternaria* sp., (F) *Penicillium* sp., (G) *Trichophyton* sp., (H) *Geotrichum candidum*.

## 4. Conclusion

The hospital wastewater results from Erbil indicate physicochemical pollution and elevated levels of fungal contamination, as several parameters have exceeded those established by environmental discharge standards. These results underscore the urgent need to construct and improve hospital wastewater treatment systems, as well as to implement ecological regulations governing hospital wastewater disposal, in accordance with local and international laws, to prevent adverse environmental and public health impacts.

## 5. Acknowledgements

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## 6. Conflicts of Interest

The authors declare that there are no conflicts of interest

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# تقييم جودة المياه والتلوث الفطري في مياه الصرف الصحي للمستشفيات في مدينة أربيل، العراق

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**الخلاصة:**

ركزت الدراسة الحالية على مياه الصرف الصحي من ثلاثة مستشفيات في أربيل: مستشفى أربيل التعليمي، ومستشفى رزكاري التعليمي، ومستشفى الطوارئ الغربي. تم جمع العينات على مدى ثلاثة أشهر (ديسمبر 2024 إلى فبراير 2025). لقياس بعض عوامل المتعلقة بجودة المياه، وعدد الفطريات، والكشف عنها. تهدف الدراسة إلى تحديد مخاطر مياه الصرف الصحي للمستشفيات من حيث مياه الصرف الملوثة، وعدد الفطريات والتحقق من أنواع الفطريات تشخيصها. أظهرت النتائج أن مياه الصرف الصحي تميزت بأنها متعادلة إلى قلوية قليلاً. كانت قيم التوصيل الكهربائي والاوكسجين الحيوي المتاح مرتفعة وتجاوزت مقاييس التصريف المحلية والدولية. فيما يتعلق بمحتوى المغذيات، كان كل من الفوسفات والنترات مرتفعين في جميع مواقع أخذ العينات. تم تشخيص ما مجموعه 13 جنسًا فطريًا، مما يشير إلى أن مياه الصرف الصحي للمستشفيات توفر بيئة مواتية لنمو الفطريات. اعلى عدد من الفطريات واكثر الانواع تم تشخيصها في مستشفى الرزگارى التعليمي حيث تم تحديد ($8300\ CFU.ml^{-1}$) و شخصت 16 نوعا من الفطريات من مامجموعه ١٩نوعا، تزامنًا مع أعلى درجة حرارة وأقل تركيز للفوسفات مقارنة بالمستشفيات الأخرى. كانت أكثر أنواع الفطريات شيوعًا التي تم اكتشافها في جميع المستشفيات التي تمت دراستها هي: *Aspergillus niger*، و*Candida albicans*، و*Geotrichum candidum*، و*Mucor* sp.، و*Penicillium* sp.. أبرزت النتائج أن خطر تلوث مياه الصرف الصحي للمستشفيات يشكل تهديدًا لكل من الصحة العامة والبيئة. لذلك، من الضروري بناء وحدات معالجة مياه الصرف الصحي ومراقبة جودة المياه المصروفة.