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Research Article

Spatial Analysis Of Surface Water Contamination With Pathogenic Fungi Resulting From Sewage Sites In Najaf Al-Ashraf Governorate

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ABSTRACT
The research aims to study the contamination of surface water with pathogenic fungi in Najaf Al-Ashraf Governorate and to determine the microbiological characteristics of the water. This was achieved through the results of laboratory analyses of sewage water samples that were collected and analyzed. Forty samples were collected from 40 locations within the study area, and 10 types of bacteria were identified for four seasons (summer, winter, spring, and autumn). These bacteria include Aspergillus spp, Aspergillus Niger, Aspergillus oryzae, Candida spp, Candida albicans, Filamentous fungi, Microconidia, Mucor, Microsporum, and Trichophyton interdigitale. The study found that pollutant concentrations vary both spatially and temporally, with spatial variations observed from one location to another and temporal variations across seasons. It was also revealed that the majority of the studied sites are not suitable for human use due to exceeding the permissible limits.

Key Words : Surface water contamination, Pathogenic fungi, Microbiological characteristics, Sewage water samples

Introduction

The study area is afflicted with microbiological water pollution, a pressing and fundamental problem that impacts the population. Water is crucial for various daily uses and agricultural purposes, making it a vital resource. Of note is that the most widespread type of pollution arises from the mixing of sewage water with surface water sources. The increase in such water poses a threat to the environment and human health, as pollution deteriorates the ecological surroundings and disrupts environmental balance. Sewage water contains substantial quantities of pathogenic microorganisms and various harmful chemical pollutants, especially when combined with industrial wastewater containing organic toxins and heavy metals. Most of these chemical pollutants have adverse health effects and harm the environment. Therefore, sewage water is one of the most dangerous problems affecting human health, largely due to the inadequacy of sewage networks [1].

1- Research Problem:
Is there spatial variation in surface water pollution caused by pathogenic fungi in the study area?

2- Research Hypothesis:
There is spatial variation in surface water pollution caused by pathogenic fungi in the study area.

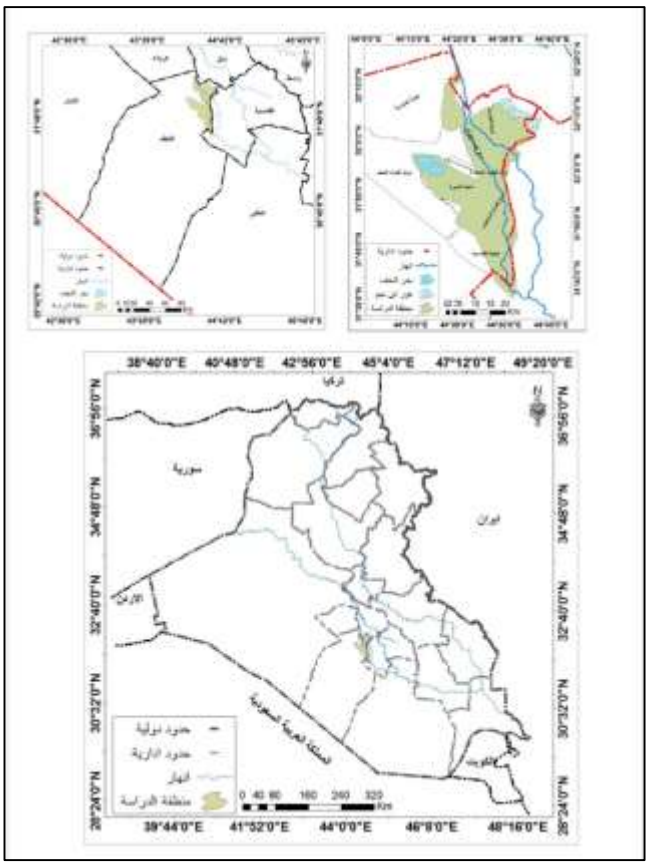
3- Study Objectives:
The study aims to determine the extent of surface water pollution resulting from sewage sites, with a focus on contamination by pathogenic fungi. It will achieve this by identifying pollutants through field sampling and laboratory analysis, assessing spatial and temporal variations.

4- Study Area Boundaries:
The study area is located in Najaf Province, which lies in the middle of Iraq, with geographical coordinates ranging between 29.50-32.21°N latitude and 42.50-45.44°E longitude. It is bounded by Karbala and Anbar

provinces to the north, Al-Qadisiyyah province to the east, Anbar province to the west, and the Kingdom of Saudi Arabia to the south, with Muthanna province to the southeast. Temporal boundaries include different seasons, focusing on the microbial study of bacteria [2].

5- Study Structure:

The research is divided into three axes:
First: Spatial variation in surface water pollution by pathogenic fungi.
Second: Results.
The study concludes with proposals, footnotes, sources, and references.



Map (1) Spatial Boundaries of the Study Area [3]

First: Spatial Variation of Surface Water Pollution by Pathogenic Bacteria in the Study Area
This research discusses the study and analysis of surface water pollution in the study area by pathogenic fungi, as well as its spatial and temporal variations, to determine the types and quantities of pathogenic fungi from one place to another and from one season to another. Samples were collected from random sites over four seasons, and (6) species were isolated and identified as follows:
Aspergillus spp: These fungi are among the most important causes of allergies and are highly prevalent. Estimates suggest that approximately 50% of individuals experience allergy symptoms related to fungi at some point in their lives. Allergic responses in most people are limited to nasal infections and asthma [4, 5]. To reduce the risk of allergy exacerbation or intensification, fungi should not be allowed to grow in indoor environments. Various species of Aspergillus have versatile features that enable them to survive in different environmental conditions. This type of pathogenic fungi is present everywhere, including in humans and animals, and is highly efficient at dispersing in the air. It can be isolated at a temperature of 37°C. It is evident from Table (1) that there is spatial and temporal variation in the growth of Aspergillus spp in the studied sewage sites. The highest growth rate was recorded during the spring and autumn seasons. This is due to suitable temperature conditions that provide the environmental conditions for the growth and proliferation of fungi. Maps (2), (3), (4), and (5) show the growth rates for fungi during the seasons. The highest growth rate was recorded in the spring season, with a total of (479) colonies. The number of colonies ranged from (5-22) cells per 1 ml. Map (5) for the spring season shows three regions: medium, high, and very high. The first medium region includes (10) sites: S2, S7, S9, S12, S22, S25, S30, S32, S40, S38. The number of colonies in this region ranges from (5-10) cells per ml. This region covers a small part from the north of Shatt Al-Kufa through the middle to the southern part, and also occupies some of the sewage sites on the banks of the Tigris River. The second high region includes (25) sites: S1, S3, S5, S6, S8, S10, S11, S13, S14, S16, S17, S20, S21, S23, S24, S26,

S27, S28, S29, S31, S33, S35, S36, S37, S39, with the number of colonies ranging from (10-15) cells per 1 ml. It covers a large area of the study area.

Table (1): Quantities of Aspergillus spp. (cells/mL) in Sewage Water for the Year (2022-2023)

Sample No.	Fall (Nov)	Spring (Apr)	Summer (Aug)	Winter (Jan)
S1	7	9	-	3
S2	9	7	5	2
S3	9	13	5	2
S4	8	17	6	2
S5	15	11	4	2
S6	10	14	5	3
S7	11	9	4	1
S8	15	12	3	2
S9	11	9	2	4
S10	14	12	5	2
S11	8	14	5	6
S12	10	7	3	1
S13	18	7	6	5
S14	10	9	7	3
S15	12	15	3	4
S16	15	12	6	2
S17	19	14	9	3
S18	16	21	10	9
S19	8	17	5	3
S20	18	12	5	2
S21	9	13	7	3
S22	12	9	5	2
S23	8	11	9	3
S24	10	13	6	4
S25	12	6	4	2
S26	14	13	5	3
S27	9	14	7	5
S28	14	12	5	1
S29	13	14	7	4
S30	16	7	3	1
S31	8	10	5	3
S32	18	9	5	1
S33	10	14	3	6
S34	9	16	8	5
S35	11	13	5	1
S36	7	10	4	2
S37	12	12	3	5
S38	7	9	3	2
S39	16	14	9	5
S40	7	9	5	2
Total	465	479	209	122

This passage describes the spatial distribution of fungal contamination, specifically Aspergillus spp, in the study area across different seasons. The study area encompasses the headwaters of the river in Al-Haydariyah district, passing through the central and southern regions of the Al-Kufa coast and appearing in some wastewater sites along the banks of the Al-Abbasia region.

The findings show variations in the distribution of Aspergillus spp contamination, both spatially and seasonally. The summer season had the fewest colonies (209), with counts ranging from 1 to 10 colonies per ml. The maps show the presence of three regions: low, medium, and high contamination.

In the fall season, which follows the summer, the total colonies reached 465, with counts ranging from 6 to 20 colonies per ml. The maps display three regions: medium, high, and very high contamination.
The passage also mentions the winter season, with the lowest number of colonies (122), ranging from 1 to 10 colonies per ml, and the presence of two regions: medium and low contamination.
It's evident that water contamination by Aspergillus spp varies both spatially and seasonally in the studied sites. The passage further discusses which regions have the highest contamination levels during specific seasons, emphasizing that all the studied sites are contaminated and unsuitable for drinking, potentially causing various health issues, such as lung inflammation, coughing, fever, chest pain, and breathing difficulties.

Aspergillus Niger:

This type is considered one of the most common species in nature and is widely distributed in the air and soil [6]. It serves as a source of contamination and can infect patients with a high degree of immunodeficiency, primarily causing bronchopulmonary aspergillosis. It can be a primary focus for its spread to other parts of the body. This fungus is known to cause chronic lung inflammation, arterial inflammation, chest pain, and its optimal temperature for growth is between 30 to 34 degrees Celsius. This makes germination difficult at the human body's temperature, which is not less than 37 degrees Celsius.
It is observed from Table (2) and Maps (6), (7), (8), and (9) that there is spatial and temporal variation in the contamination of wastewater by Aspergillus Niger bacteria. The contamination varies both in space and time throughout the seasons. The highest growth rate for the fungus was recorded during the spring season, with a total of 526 colonies and colony counts ranging from 5 to 25 colonies per ml. Map (9) for the spring season shows the appearance of three regions: medium, high, and very high. The medium region appears in 16 sites, including S1, S13, and S14.

Table (2): Aspergillus niger Fungus Colony Counts (per 1 ml) in Sewage Water for the Year 2022-2023.

Preparation of bacteria in the spring (April)	Preparation of bacteria in the spring (April)	Bacteria preparation in summer (August)	Bacteria numbers in winter (January)	Sample
12	10	5	2	S1
19	24	15	9	S2
15	21	9	8	S3
12	19	8	4	S4
9	15	9	4	S5
9	14	4	2	S6
15	19	6	9	S7
9	13	4	3	S8
8	12	3	2	S9
9	13	4	2	S10
14	9	3	6	S11
9	8	3	5	S12
11	16	5	3	S13
13	15	4	3	S14
13	10	3	3	S15
10	12	2	2	S16
12	14	2	2	S17
8	10	6	2	S18
10	12	4	5	S19
9	15	4	6	S20
7	10	5	2	S21
10	9	4	2	S22
8	13	3	5	S23
6	10	4	5	S24
10	14	5	3	S25
9	19	4	4	S26
7	9	3	2	S27
9	11	2	1	S28
7	12	3	2	S29
10	13	6	3	S30
8	16	4	4	S31
7	9	3	3	S32
9	11	6	2	S33
14	19	4	5	S34
13	10	2	3	S35
11	19	4	5	S36
12	9	3	7	S37
12	13	4	3	S38

12	9	4	7	S39
13	10	4	4	S40
420	526	180	154	Total

Colonies of (Aspergillus niger) vary between (5-10) cells/ml, and the spatial distribution appears on the north bank of the Kufa River and extends to the southern part, also occupying some sewage sites along the Abbasid River. In contrast, the second high region appears in (16) locations, namely (S6, S8, S9, S10, S11, S12, S15, S16, S18, S19, S22, S24, S28, S29, S30, S38) and occupies a very small portion of the sites north of the Kufa River, extending to the central and southern parts of it, and then extending to scattered locations along the Abbasid River. As for the very high third region, it appears in (8) locations, which are (S2, S3, S4, S5, S7, S25, S33, S35), with the number of colonies ranging from (10-15) cells/ml, occupying a limited part of the study area. The autumn season comes in second place in the total number of colonies, reaching (420) colonies, with the number of colonies ranging from (5-19) cells/ml. Map (7) for the autumn season shows the appearance of three regions, namely (medium, high, very high). The first medium region appears in (18) locations, namely (S5, S6, S8, S9, S10, S11, S12, S18, S20, S21, S23, S24, S26, S27, S28, S29, S31, S32), with the number of colonies ranging from (5-10) cells/ml. This region occupies a part of the northern part of the Kufa River, extending to the central and southern parts, and occupying a part of the sewage sites on the Abbasid River. The second high region appears in (19) locations, namely (S1, S4, S13, S14, S15, S16, S17, S19, S22, S25, S30, S33, S34, S35, S36, S37, S38, S39, S40), with the number of colonies ranging from (10-15) cells/ml. This region occupies scattered locations on the banks of the Kufa and Abbasid rivers. As for the fourth very high region, it appears in (3) locations, namely (S2, S3, S7), with a number of colonies ranging from (19, 15, 15) cells/ml, and this region extends in a narrow and limited area of the study. The summer season comes in third place with a total number of colonies (180 cells/ml), with the number of colonies ranging from (1-10) cells/ml. Map (6) for the summer season shows the appearance of two regions (few, medium). The first few regions appear in (30) locations, namely (S1, S6, S8, S9, S10, S11, S12, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S26, S25, S27, S28, S29, S31, S32, S34, S35, S36, S38, S39, S40), with the number of colonies ranging from (1-5) cells/ml. This region occupies wide and scattered areas of the study. The second medium region appears in (10) locations, namely (S2, S3, S4, S5, S7, S13, S18, S21, S30, S33), with the number of colonies ranging from (5-10) cells/ml. The winter season occupies the last place in the total number of colonies, reaching (154) colonies, with the number of colonies ranging from (1-10) cells/ml. Map (8) for the winter season shows the appearance of two regions (few, medium). The first few regions appear in (28) locations, namely (S1, S4, S5, S6, S8, S9, S10, S13, S14, S15, S16, S17, S18, S21, S22, S23, S25, S26, S28, S27, S29, S30, S31, S32, S34, S35, S40, S38), with the number of colonies ranging from (1-5) cells/ml. This region occupies most of the study area. The second medium region appears in (12) locations, namely (S2, S3, S7, S11, S12, S19, S20, S24, S36, S34, S37, S39), with the number of colonies ranging from (5-10) cells/ml. Its spatial extension appears on the north bank of the Kufa River and extends to the central part, down to the south of the river, and then appears in scattered locations along the Abbasid River. It is clear that the highest presence of (Aspergillus niger) was during the (spring and autumn) seasons due to the favorable conditions for the growth and reproduction of the fungus in sewage water, making this water contaminated and unsuitable for human use. Discharging this contaminated water into surface waters in the study area without treatment and filtration results in water pollution, making it unsuitable for drinking by the residents, exposing them to various diseases [7].

Aspergillus oryzae Fungus: It is a filamentous fungus used in Japanese and Chinese cuisine for fermenting soybeans to produce soy sauce. It lacks the ability for sexual reproduction and is a native species. Therefore, it can be found in a domesticated form but not in the natural environment. Aspergillus oryzae fungus contains a wide range of water-degrading enzymes (4).

The table (3) and maps (10), (11), (12), and (13) reveal spatial and temporal variations in the growth of Aspergillus oryzae fungi in wastewater within the studied locations. There are spatial variations from one location to another and temporal variations across different seasons. The highest fungal growth is recorded during the spring and autumn seasons, attributed to the moderate temperatures that provide a suitable environment for fungal growth. The spring season occupies the top position in the total fungal counts, reaching 647 colonies with counts ranging from 5 to 30 cells/ml. Map (13) illustrates the presence of three regions (Medium, High, Very High) during the spring season. The Medium region is observed in 5 locations (S3, S14, S24, S27, S30) with fungal counts ranging from 5 to 10 cells/ml.

Table (3): Aspergillus oryzae Fungal Counts (cells/ml) in Wastewater for the Year 2022-2023.

Preparation of bacteria in the spring (April)	Preparation of bacteria in the spring (April)	Bacteria preparation in summer (August)	Bacteria numbers in winter (January)	Sample
11	14	6	4	S1
9	12	7	2	S2
13	9	5	1	S3
14	21	10	6	S4

12	14	7	3	S5
13	10	6	4	S6
21	15	3	9	S7
17	12	6	4	S8
10	17	6	2	S9
14	19	10	5	S10
21	14	8	6	S11
20	24	12	4	S12
27	22	9	1	S13
5	9	2	5	S14
13	21	8	5	S15
14	24	9	4	S16
13	25	14	5	S17
12	15	9	3	S18
14	13	9	4	S19
11	11	6	5	S20
12	17	8	4	S21
14	23	10	9	S22
11	13	6	5	S23
14	9	4	2	S24
12	16	6	5	S25
10	13	6	4	S26
13	9	7	2	S27
14	19	7	3	S28
14	14	10	4	S29
13	5	5	9	S30
13	19	5	5	S31
12	10	4	2	S32
11	12	1	4	S33
12	15	4	9	S34
29	14	12	10	S35
15	21	10	5	S36
12	23	9	6	S37
12	29	12	9	S38
11	21	9	5	S39
29	24	12	4	S40
567	647	299	188	**Total**

The spatial distribution of this region is represented by a small area to the north of Al-Kufa Canal and a portion in the center, extending to the south of the canal. It also appears in some wastewater sites along the Al-Abbassiya Canal. As for the second high region, it consists of 14 locations, namely S1, S2, S5, S6, S7, S8, S11, S19, S20, S23, S26, S29, S33, and S35, with colony numbers ranging from 10 to 15 cells/ml. It covers an extensive scattered area, stretching from the north of Al-Kufa Canal to its south and is also observed in a small part of the wastewater sites along the Al-Abbassiya Canal.

On the other hand, the third high region is found in 21 locations, including S4, S9, S10, S12, S13, S15, S16, S39, S17, S18, S21, S22, S25, S28, S30, S32, S34, S36, S37, and S38, with colony numbers ranging from 15 to 30 cells/ml. This region covers extensive and scattered areas from the north to the south of Al-Kufa Canal and also extends along the Al-Abbassiya Canal. The autumn season comes in second place in terms of the total colony count, with 567 colonies recorded, ranging from 5 to 30 cells/ml. It's worth noting that there are three regions: low, medium, and high, with the medium region being represented by S2 and S14, each having 9 and 5 colonies per ml, respectively. This region covers a very small part of the study area.

The high region, however, is observed in 29 locations, including S1, S3, S5, S4, S6, S9, S10, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S29, S28, S30, S31, S32, S33, S34, S35, S37, S38, and S39, with colony numbers ranging from 10 to 15 cells/ml. This region covers large and scattered areas throughout the study area. Lastly, the third very high region appears in 7 locations: S7, S8, S11, S12, S13, S36, and S40, with colony numbers ranging from 15 to 30 cells/ml. It extends in a limited part from the north to the south of Al-Kufa Canal and also appears in a very small area along the Al-Abbassiya Canal.

During the summer season, the growth counts decrease compared to the spring and autumn seasons, with a total of 299 colonies, ranging from 1 to 15 cells/ml. The map of the summer season shows three regions: low, medium, and high. The low region is represented by 5 locations: S7, S14, S24, S32, and S34, each having colony numbers ranging from 1 to 5 cells/ml, and it is mostly located in the central part of Al-Kufa Canal, extending to a very small portion of the Al-Abbassiya Canal.

The high region is observed in 22 locations: S1, S2, S3, S5, S6, S8, S9, S11, S13, S15, S16, S18, S19, S20, S21, S23, S25, S26, S27, S28, S30, and S31, with colony numbers ranging from 5 to 10 cells/ml. It extends across various locations from the north to the south of Al-Kufa Canal, with some scattered locations along the Al-Abbassiya Canal. The very high region is seen in 13 locations: S4, S10, S12, S17, S22, S29, S33, S35, S36, S37, S38, S39, and S40, with colony numbers ranging from 10 to 15 cells/ml. It covers scattered areas on both the Al-Kufa and Al-Abbassiya Canals.
The winter season ranks the lowest in terms of colony count, with a total of 188 colonies, ranging from 1 to 10 cells/ml. The map of the winter season shows two regions: low and medium. The low region is represented by 21 locations: S1, S2, S3, S5, S6, S8, S9, S12, S13, S16, S18, S19, S21, S24, S26, S27, S28, S29, S32, S40, and S33, with colony numbers ranging from 1 to 5 cells/ml. It covers the front of the canal, certain wastewater sites in Al-Haydariya district, the central part of Al-Kufa Canal, and small portions along the Al-Abbassiya Canal. The medium region appears in 19 locations: S4, S7, S10, S11, S14, S15, S17, S20, S22, S23, S25, S30, S31, S34, S35, S36, S37, S38, and S39, with colony numbers ranging from 5 to 10 cells/ml. This region covers scattered locations on both the Al-Kufa and Al-Abbassiya Canals.
It is evident from the above that all the studied sites suffer from clear contamination by Aspergillus oryzae fungus. Site 33 recorded the highest growth during the spring season, with 22 cells/ml. It is apparent that wastewater contains numerous pollutants resulting from various domestic and agricultural uses. Thus, untreated wastewater provides a suitable environment for the growth of microorganisms of various types, making these waters highly polluted. They must be properly treated before being discharged into the river. The use of this untreated wastewater exposes residents to various diseases.

Fungus (Candida spp) - Yeast Infections:
Yeast infections are present everywhere, primarily on mucous surfaces in the human body, such as the digestive system and the urogenital tract. They mostly cause gaseous diseases resulting from changes in the natural microbiological balance or the penetration of the mucosal skin barrier. Candida spp infections can manifest in a wide range of clinical conditions, including disseminated candidiasis, deep tissue infections such as intra-abdominal infections, peritonitis, meningitis, eye infections.

Table (4) shows the counts of Candida spp per 1 ml in sewage waters for the year 2022-2023.
It can be observed from Tables (4) and the maps (14), (15), (16), and (17) that there is spatial and temporal variation in the contamination of sewage waters with Candida spp. This contamination varies from one place to another and across seasons. The highest fungal growth counts are recorded during the spring and autumn seasons, attributed to the moderate temperatures. Fungal growth counts decrease during the summer and winter seasons due to temperature differences that do not favor the growth and proliferation of fungi.
The spring season ranks first in terms of fungal growth counts, with a total of 526 colonies. Map (17) for the spring season reveals three regions: medium, high, and very high. The medium region is represented by 9 locations: S17, S18, S20, S23, S30, S36, S35, S37, and S39, with colony counts ranging from 6 to 10 cells per 1 ml. This region appears in the south of Al-Kufa Canal and extends to the Al-Abbassiya Canal. The high region is observed in 23 locations: S2, S3, S4, S5, S6, S8, S9, S13, S15, S16, S19, S21, S22, S24, S26, S28, S29, S31, S32, S33, S34, S38, and S40, with colony counts ranging from 10 to 15 cells per 1 ml. This region is located north of the river in Al-Haydariya district and extends to the center and south of Al-Kufa Canal. It also appears in some extended locations along the Al-Abbassiya Canal.
On the other hand, the very high region is found in 7 locations: S1, S7, S10, S11, S12, S14, and S27, with colony counts ranging from 15 to 27 cells per 1 ml. The spatial extension of this region is narrow and limited within the study area.
The autumn season ranks second in the total colony counts, with a total of 384 colonies, ranging from 5 to 23 cells per 1 ml. Map (15) for the autumn season reveals three regions: medium, high, and very high. The medium region is observed in 22 locations: S2, S3, S8, S9, S14, S15, S17, S19, S20, S22, S23, S25, S26, S28, S29, S31, S30, S33, S34, S35, S36, S37, and S39, with colony counts ranging from 5 to 10 cells per 1 ml. This region covers extensive areas within the study area. The high region is present in 15 locations: S1, S4, S5, S6, S7, S11, S3, S12, S16, S18, S21, S27, S32, S40, and S38, with colony counts ranging from 10 to 15 cells per 1 ml. It extends from the north of Al-Kufa Canal to the center and south of the study area, with some locations along the Al-Abbassiya Canal. The very high region is observed in 3 locations: S10, S13, and S24, with colony counts ranging from 15 to 23 cells per 1 ml.
The summer season ranks third in the total colony counts, with a total of 250 colonies, ranging from 1 to 18 cells per 1 ml.

Table (4) Candida spp Fungus Counts per 1 ml for Sewage Waters for the year 2022-2023.

Preparation of bacteria in the spring (April)	Preparation of bacteria in the spring (April)	Bacteria preparation in summer (August)	Bacteria numbers in winter (January)	Sample
15	22	12	9	S1

9	11	6	3	S2
8	12	3	5	S3
13	10	4	3	S4
11	14	10	2	S5
10	13	6	4	S6
12	16	10	2	S7
8	12	5	3	S8
6	14	5	1	S9
21	26	17	9	S10
12	21	14	3	S11
10	18	6	1	S12
18	14	10	2	S13
9	27	15	9	S14
9	13	12	3	S15
10	10	9	2	S16
9	9	6	3	S17
11	8	4	1	S18
9	13	6	4	S19
7	9	1	2	S20
10	12	6	3	S21
8	14	5	3	S22
5	9	4	1	S23
22	15	10	4	S24
9	14	6	3	S25
6	13	4	2	S26
11	22	5	7	S27
7	14	4	3	S28
6	11	3	2	S29
5	9	4	1	S30
7	10	3	4	S31
10	14	6	5	S32
6	11	4	1	S33
9	13	4	5	S34
6	9	2	4	S35
9	7	3	1	S36
4	6	3	1	S37
12	11	6	5	S38
4	7	1	3	S39
11	13	6	5	S40
384	526	250	134	Total

The map (14) for the summer season reveals the presence of four regions: low, medium, high, and very high. The first region is represented in 16 locations (S3, S4, S18, S20, S23, S26, S28, S29, S30, S31, S33, S34, S35, S36, S37, S39), with colony counts ranging from 1 to 5 cells per 1 ml. The spatial extension of this region covers from the north of the Kufa river to the central region, continuing south of the study area. It also appears in some sewage sites along the Abbasid riverbank.

The second region, medium, is visible in 15 locations (S2, S6, S8, S9, S12, S16, S17, S19, S21, S22, S25, S27, S32, S38, S40), with colony counts ranging from 5 to 10 cells per 1 ml. This region extends from the north of the Kufa river to its south and appears in some sewage sites extending along the Abbasid riverbank and in the western part of the study area.

The third region, high, includes 7 locations (S1, S5, S7, S11, S13, S15, S24), with colony counts ranging from 15 to 27 cells per 1 ml. The spatial extension is limited to a small section north of the river, extending south of the study area. The very high region consists of 2 locations (S10, S14), with colony counts of 15 and 17 calls per 1 ml.

The winter season ranks the lowest in total colony counts, with 134 colonies and counts ranging from 1 to 10 cells per 1 ml. The map (16) for the winter season shows two regions, low and medium. The low region is represented in 31 locations, with colony counts ranging from 1 to 5 cells per 1 ml, covering most of the study area. The medium region appears in 9 locations (S1, S3, S10, S14, S27, S32, S34, S40, S38) with colony counts ranging from 5 to 10 cells per 1 ml, extending to various scattered locations along the Kufa and Abbasid riverbanks [8].

Table (4) indicates the contamination of all the studied sites with Candida spp. This contamination varies both spatially and temporally. Candida spp was most prevalent during the spring and autumn seasons, with counts decreasing during the summer and winter seasons. This variation can be attributed to the differences in temperature, with moderate temperatures during spring and autumn creating favorable conditions for fungal growth. Consequently, these contaminated waters pose significant health risks to the population and can lead to various diseases. Site S14 showed the highest contamination during the spring season, with 27 colonies per 1 ml.

Candida albicans is one of the very few fungal species that can cause diseases in humans, as opposed to the millions of other species that do not. Infections with Candida albicans are particularly severe in individuals with weakened immune systems, such as those with AIDS, or those undergoing cancer treatment, as well as in healthy individuals with implanted medical devices. Candida albicans produces highly regulated biofilms consisting of various cell types, including yeast-like cells, oval pseudohyphal cells, and elongated cylindrical cells enclosed within an extracellular matrix outside the cell. It is the fourth most common cause of bloodstream infections in clinical settings. Candida albicans is present in the oral cavity of up to 75% of healthy individuals, and this colonization is generally benign. However, individuals with compromised immunity may occasionally suffer from persistent infections in the oral cavity, referred to as "oral candidiasis," which can affect the palate and esophagus, especially in individuals with impaired immune function [9].

Laboratory analysis of sewage water (Table 5) shows clear contamination with Candida albicans. This contamination varies both spatially and temporally. The maps (18), (19), (20), and (21), which indicate colony counts during different seasons, reveal that the highest presence of fungal growth occurred during the spring season. The total colony count during spring reached 421 colonies, with counts ranging from 1 to 21 cells per ml. Map (21) illustrates three regions: medium, high, and very high. The medium region is represented in 17 locations (S1, S2, S4, S5, S9, S10, S12, S14, S18, S21, S24, S26, S30, S31, S34, S36, S37), with colony counts ranging from 5 to 10 cells per 1 ml. The spatial extension covers scattered sewage locations in Al-Haydariyah district and then extends to the central Kufa riverbank to the south of the study area, in addition to a limited area on the Abbasid riverbank.

The high region appears in 15 locations (S3, S8, S13, S16, S17, S19, S23, S27, S28, S29, S32, S33, S38, S39, S40), with colony counts ranging from 10 to 15 cells per 1 ml. It extends from the north to the south of the Kufa river and is also visible in the waters of Al-Najaf in addition to some locations on the Abbasid riverbank. The very high region is observed in 8 locations (S6, S8, S11, S15, S20, S22, S25, S35), with colony counts ranging from 15 to 21 cells per 1 ml. This region occupies a limited area of the study region, with a small part extending from the north to the south of the Kufa river and a very small area along the Abbasid riverbank. The autumn season is ranked...

Table 5: Colony counts of Candida albicans (cells/ml) in sewage water for the year 2022-2023.

Preparation of bacteria in the spring (April)	Preparation of bacteria in the spring (April)	Bacteria preparation in summer (August)	Bacteria numbers in winter (January)	Sample
10	5	0	2	S1
9	8	4	9	S2
7	10	5	2	S3
12	5	3	0	S4
10	7	1	2	S5
12	15	2	10	S6
12	16	9	10	S7
9	11	4	0	S8
9	7	4	3	S9
15	6	0	2	S10
16	15	9	7	S11
10	8	6	2	S12
10	11	6	5	S13
17	8	5	3	S14
8	20	5	10	S15
5	13	9	4	S16
10	12	8	2	S17
9	6	4	0	S18
10	12	4	8	S19
8	18	5	3	S20
9	9	4	1	S21
10	17	7	3	S22

6	**12**	**4**	**2**	**S23**
22	**5**	**6**	**1**	**S24**
11	**15**	**9**	**5**	**S25**
5	**9**	**0**	**2**	**S26**
16	**13**	**8**	**9**	**S27**
7	**10**	**6**	**1**	**S28**
6	**11**	**3**	**2**	**S29**
9	**8**	**5**	**1**	**S30**
9	**6**	**5**	**1**	**S31**
10	**13**	**6**	**2**	**S32**
6	**11**	**4**	**9**	**S33**
9	**6**	**0**	**4**	**S34**
9	**15**	**3**	**10**	**S35**
8	**9**	**2**	**6**	**S36**
7	**5**	**0**	**2**	**S37**
12	**10**	**4**	**9**	**S38**
9	**12**	**5**	**5**	**S39**
10	**12**	**6**	**4**	**S40**
398	**421**	**180**	**163**	**Total**

The second highest in terms of the total number of colonies (398 colonies), with counts ranging from 5 to 23 cells per 1 ml. Map (19) for the autumn season reveals the presence of three regions: medium, high, and very high. The medium region is represented in 21 locations (S2, S3, S8, S9, S15, S16, S18, S20, S21, S23, S26, S28, S29, S30, S31, S33, S34, S35, S36, S37, S39), with colony counts ranging from 5 to 10 cells per 1 ml. This region occupies extensive and scattered areas along the river.
The high region appears in 16 locations (S1, S4, S5, S6, S7, S11, S12, S13, S17, S19, S22, S25, S27, S32, S38, S40), with colony counts ranging from 10 to 15 cells per 1 ml. The very high region occupies 3 locations (S10, S14, S22), with colony counts of 15, 17, and 22 cells per 1 ml, respectively. This region has a very limited presence in the study area.

6- Filamentous Fungi: These are multi-purpose organisms with a significant impact on industrial fermentation. These fungi serve as a source of various compounds, such as those related to medicines, alkaloids, polysaccharides, stimulants, organic acids, and pigments. Filamentous fungi are also used in the industrial production of important enzymes. These fungi are natural sources of biologically active drugs with antimicrobial, anticancer, and anti-inflammatory properties. Filamentous fungi, as true-nucleated organisms, have unique characteristics, such as heterotrophic nutrition and the development of reproductive and vegetative structures. These fungi are common in environments with high humidity and a predominant aerial interface and are multicellular, composed of structures called hyphae [10].
Table (6) and maps (22), (23), (24), and (25) show that this type of fungus varies both spatially and temporally. The spatial variation occurs from one location to another, and temporally, it varies throughout the seasons. The numbers of cell growth increase during the spring and autumn seasons due to moderate temperatures. The numbers of growth decrease during the summer and winter seasons. In the spring season, it ranks first in terms of the total number of colonies (763 colonies) with counts ranging from 9 to 30 cells per 1 ml. Map (25) for the spring season indicates three regions: medium, high, and very high. The medium region appears in only one location (S2) with 9 colonies per 1 ml. The spatial extension of this region covers a small part of the north. The high region is represented in 18 locations (S1, S3, S9, S12, S13, S14, S15, S16, S18, S23, S28, S29, S30, S33, S34, S35, S36, S38), with colony counts ranging from 10 to 15 cells per 1 ml. This region occupies a very small area from the north to the south of the river, in addition to some areas along the Abbasid riverbank. The very high region appears in 21 locations (S4, S5, S6, S7, S8, S11, S10, S17, S19, S20, S21, S22, S24, S25, S26, S27, S31, S32, S37, S39, S40), with colony counts ranging from 15 to 30 cells per 1 ml. The spatial extension covers a small part of the north of the Kufa river.

Table (6) Counts of Filamentous Fungi (per 1 ml) for Wastewater in the Year 2022-2023.

Preparation of bacteria in the spring (April)	Preparation of bacteria in the spring (April)	Bacteria preparation in summer (August)	Bacteria numbers in winter (January)	Sample
14	19	9	5	S1
11	9	4	1	S2
19	13	9	5	S3
18	22	9	6	S4

19	24	8	9	S5
15	20	3	8	S6
18	24	8	9	S7
13	16	4	9	S8
9	12	4	3	S9
16	22	9	6	S10
17	21	8	9	S11
10	19	4	4	S12
11	12	4	5	S13
13	10	4	4	S14
21	17	8	9	S15
14	19	9	10	S16
18	21	4	4	S17
21	14	9	5	S18
26	21	10	9	S19
24	29	14	10	S20
15	27	9	5	S21
25	28	9	9	S22
9	12	4	5	S23
19	22	9	10	S24
16	21	4	9	S25
10	22	3	4	S26
17	21	8	6	S27
11	16	4	5	S28
9	12	3	5	S29
14	19	9	5	S30
17	24	12	5	S31
24	29	15	9	S32
14	19	9	5	S33
10	13	4	6	S34
9	16	4	2	S35
22	19	9	5	S36
13	21	3	4	S37
11	16	9	2	S38
13	21	1	5	S39
14	21	4	9	S40
619	763	273	245	Total

Also, it appears in some locations along the Abbasid River bank. As for the autumn season, it ranks second in terms of the total colony counts, with a total of 619 colonies per ml and colony counts ranging from 10 to 30 per 1 ml. Map (23) for the autumn season illustrates the presence of three regions: medium, high, and very high. The medium region is found in four locations: S9, S23, S29, and S35, with colony counts ranging from 9 to 10 per 1 ml. This region occupies a limited area within the study region. The high region is represented in 19 locations: S1, S2, S8, S10, S11, S12, S13, S14, S16, S21, S25, S26, S28, S30, S33, S34, S37, S38, and S39, with colony counts ranging from 10 to 15 per 1 ml. Its spatial distribution extends from the north of the Kufa bank to the south and includes a part of scattered sites along the Abbasid River bank. The very high region is found in 17 locations: S3, S4, S5, S6, S6, S7, S15, S17, S18, S19, S20, S22, S24, S27, S31, S32, and S36, with colony counts ranging from 15 to 30 per 1 ml. This region includes a part of the sewage sites in Al-Haydariya district and extends through the central and southern parts of the Kufa bank. It also occupies scattered sites along the Abbasid River bank.

On the other hand, the summer season ranks third in terms of the total colony counts, with a total of 273 colonies per ml, and colony counts ranging from 1 to 15 per 1 ml. Map (22) for the summer season shows the presence of three regions: few, medium, and high. The few region is found in 18 locations: S2, S6, S8, S9, S12, S13, S14, S17, S23, S25, S28, S26, S29, S34, S35, S37, S39, and S40, with colony counts ranging from 1 to 5 per 1 ml. This region appears in a small part extending from the north of the Kufa bank, through the central and southern parts, and occupies a small area along the Abbasid River bank. It is also visible west of the study region. The medium region is found in 17 locations: S1, S3, S4, S5, S7, S10, S11, S15, S16 S18, S21, S22, S27, S30, S33, S36, S38, with colony counts ranging from 5 to 10 per 1 ml. Its spatial distribution extends from the north of the Kufa bank to the south and is also visible in scattered sites along the Abbasid River bank.

The high region is found in 5 locations: S19, S20, S24, S31, and S32, with colony counts ranging from 10 to 15 per 1 ml. Then, the colony counts decrease during the winter season, making it the season with the fewest colonies, totaling 245 colonies per ml, and colony counts ranging from 1 to 10 per 1 ml. Map (24) for the winter season shows the presence of three regions: few, medium, and high. The few regions are found in 9 locations:

S2, S9, S12, S12, S14, S26, S35, S37, S38, with colony counts ranging from 1 to 5 per 1 ml. This region appears in a small area extending from the north of the river at a sewage site on Bani Hassan River. It continues to the central part of the Kufa bank, reaching the southern part, and also occupies a small area along the Abbasid River bank.
The medium region is found in 28 locations: S1, S3, S4, S5, S6, S7, S8, S10, S11, S13, S15, S17, S18, S21, S22, S23, S25, S27, S28, S29, S30, S31, S32, S33, S34, S36, S39, S40, with colony counts ranging from 5 to 10 per 1 ml. Its spatial distribution covers a wide range, including most of the study area. The high region is found in 3 locations: S16, S20, and S24, with 10 colonies per ml. This region is present in a limited area within the study, located in the central and southern parts of the Kufa bank.

Second - Results

The research has yielded several results that can be summarized as follows:
The results of laboratory tests on wastewater in the studied locations showed spatial and temporal variations in the growth of fungi. These fungi exhibited spatial variation from one location to another and grew and multiplied during the spring and autumn seasons while decreasing in number during the summer and winter seasons.
Discharging untreated wastewater into surface waters has exacerbated the problem of pollution.
The surface waters in most of the studied locations are unsuitable for human use due to exceeding the permissible limits.
The lack of highly efficient treatment units has contributed to the deterioration of surface waters in the study area.
The study has identified several regions for bacterial types based on the maps, including few, medium, high, and very high regions.
The statistical simulations were consistent with the results of laboratory tests for pathogenic fungi.

Proposed Solutions:
Given the problems facing the study area, several proposed solutions have been developed to reduce surface water pollution:
Raise environmental and cultural awareness among the area's residents to reduce environmental pollution.
Enact legislation to protect surface waters from pollution in the study area.
Conduct annual and continuous studies to track changes throughout the year to identify pollutants and their sources.
Establish highly efficient treatment units at hospitals to dispose of contaminants before discharging them to treatment plants, as these contaminants contain many germs and viruses (pathogenic fungi).
The Directorate of Water and Sewage should establish multiple pumping stations and distribute them properly in the study area.
Create technically and scientifically qualified teams to identify sewage stations and their design capacities, ensuring they are located away from residential areas to mitigate foul odors.

Conclusions

The research aimed to investigate the contamination of surface water with pathogenic fungi in Najaf Al-Ashraf Governorate and to characterize the microbiological properties of the water. This objective was accomplished by conducting laboratory analyses of sewage water samples that were collected and examined. A total of forty samples were obtained from various locations within the study area, and ten types of bacteria were identified across four seasons (summer, winter, spring, and autumn). These bacteria included Aspergillus spp, Aspergillus Niger, Aspergillus oryzae, Candida spp, Candida albicans, Filamentous fungi, Microconidia, Mucor, Microsporum, and Trichophyton interdigitale. The study revealed that pollutant concentrations exhibit both spatial and temporal variations. Spatial differences were observed from one location to another, while temporal variations occurred across different seasons. Furthermore, it was evident that the majority of the surveyed sites exceeded the permissible limits, rendering them unsuitable for human use. These findings highlight the pressing need for environmental management and remediation strategies to address surface water contamination in Najaf Al-Ashraf Governorate.

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