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Investigation of Microbial Contamination in Tap Water and Domestic Tanks in Some Areas of Basrah Governorate, Iraq

Enas A. Mahdi Al-Nabhan[1], Halah Awni Mahdi[2], and Nassir Abdullah Alyousif[1*]

[1]*Department of Ecology, College of Science, University of Basrah, Basrah, Iraq*
[2]*Fire Department, Health Safety and Environment Division, Basrah Oil Company, Iraq*

*Corresponding author: nassir.hillo@uobasrah.edu.iq
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Abstract

Water pollution is one of the main dangers that threaten the lives of all living organisms, particularly humans. Microbial investigation is commonly employed to indirectly detect the presence of pathogenic bacteria in water. This study aims to examine the microbial content in tap water and household tank samples from various areas in Basrah governorate by measuring total bacterial content, total coliforms, fecal coliforms, and fungal contamination. Thirty samples were collected from 15 residential areas supplied with tap water, with three replicates for each sample. All collected samples of tap water and household tanks were analyzed for microbial content. The results of the microbial investigation indicated that all samples were contaminated with high levels of total bacteria, total coliforms, fecal coliforms, and fungi. Microbial examination parameters showed severe contamination of 100% according to WHO standards in all tested water samples. While some samples were highly polluted, others exhibited lower levels of pollution but still exceeded permissible limits for various domestic uses according to WHO standards. The fungal examination revealed the isolation and identification of anamorphic fungi from the water samples, with most species belonging to *Aspergillus*, particularly *Aspergillus niger*. Consequently, the study concluded that both tap water and tank water in Basrah governorate are unsuitable and unsafe for human consumption. Therefore, there is an urgent need for stringent monitoring of water treatment plants and strict compliance with health protocols.

Keywords: Total bacteria count; Total coliforms; Fecal coliforms; Tap water; Basrah province

1. Introduction

Water is one of the most vital components of life on Earth and the key factor for its continuity. It is essential for all forms of life and it is directly or indirectly connected to every aspect of human activity. The world, especially developing countries, faces one of the most serious challenges humanities have encountered which is the provision of clean drinking water (Bănăduc *et al.,* 2022; Al-Khafaji *et al.,* 2025). Water has acquired great importance, making it the primary factor determining life as well as agricultural and industrial production. The availability of fresh water in all parts of the Earth was a reason for the emergence and prosperity of civilizations due to their proximity to water sources, while the extinction of many of these civilizations was due to water scarcity and its decline (Mahdi and Al-Abbawy, 2019; Al-Jaberi and Al-Abbawy, 2023; Al Khafaji *et al.,* 2024).

Although water covers about 70% of the Earth's surface, 97% of this water is found in seas and oceans, which contain a high percentage of salts, making it unsuitable for

various uses without expensive treatments. Out the remaining 3%, 80% is found in the form of ice at the North and South Poles, and 10% exists as groundwater at depths exceeding 800 meters, resulting in high exploitation costs. Consequently, only about 0.3% of the total water available on the Earth's surface is fresh water, representing the amount that can be used for domestic, industrial, and agricultural purposes (Nallakukkala and Lal, 2021).

Increased population density and the industrial revolution have negatively impacted water quality and its suitability for various uses, affecting human health. Therefore, it is imperative to address the problems and risks caused by water pollution, which can lead to a shortage of potable water supply. City residents consume an average of 70 gallons of water per person per day, with approximately 50 gallons lost to wastewater (Lin *et al.,* 2022; Babuji *et al.,* 2023). Water pollution is one of the main dangers that threaten the lives of all living organisms, especially human life. Therefore, drinking water must be free of chemical, physical, and biological pollutants, and it must be palatable, being colorless, tasteless, and odorless (Lin *et al.,* 2022; Al Khafaji *et al.,* 2023).

Drinking water quality can be assessed through biological and physico-chemical evaluations (Saraswat *et al.,* 2022). Contamination from organic and inorganic pollutants adversely affects both the environment and human health (Mohammad *et al.,* 2021). Microbial investigation is typically used to indirectly detect the presence of pathogenic bacteria in water. The coliform bacteria group, which is part of the Enterobacteriaceae family, is one of the most significant indicators of water contamination with fecal matter. This group includes bacterial flora found in the human intestine, such as *Escherichia coli* and *Enterobacter* spp, as well as pathogenic bacteria like *Salmonella* spp., *Shigella* spp., and *Vibrio cholerae* (Richiardi *et al.,* 2023). Fecal indicator bacteria are commonly used to assess the presence of pathogenic microorganisms in water. *E. coli*, fecal coliforms, and fecal streptococci are frequently employed as indicators. These bacteria are valuable for evaluating microbial water quality and developing appropriate risk mitigation strategies (Haldar *et al.,* 2022).

Iraq is one of the countries in the world that suffers from the problem of water pollution, but to a greater extent due to the scarcity of rain and the decline in water levels related to river sources. The exposure of water to various sources of pollution in different proportions, such as agricultural and industrial pollutants and sewage water, causes a scarcity of water in general and potable water in particular (Todd, 2024). The Basrah governorate depends on the waters of the Shatt al-Arab River and freshwater canals as its main sources of water for drinking, irrigation, and other purposes. There are several water treatment plants in Basrah governorate, and the quality of drinking water in most treatment plants has been the subject of numerous studies. The results of these studies have varied from one to another, depending on seasonal changes and the solutions developed by the government to address the problems of access to safe drinking water (Almuktar *et al.,* 2020). This research addresses an important accumulated problem, which is the provision of clean water suitable for human use and reducing the water contamination because of its direct impact on people's health, which leads to many diseases. The aim of this study is to determine the suitability of tap water supplied to homes in Basrah governorate for various domestic uses, and this aim has been achieved by investigate the microbial content in tap water and household tank samples in some areas of Basrah governorate by detecting the total bacterial content, total coliforms, fecal coliforms, and fungal contamination to evaluate the suitability of tap water for various domestic uses and to ensure the effectiveness of sterilization and filtration methods used in water treatment plants.

2. Methodology

2.1 Study area and sample collection

The study areas included collecting samples of tap water and household tanks from various locations in Basrah governorate, covering 15 residential areas as shown in Figure 1 and Table 1. In the current study, 30 samples were collected from residential areas equipped with tap water, with three replicates for each sample, to detect microbial

contamination (bacteria and fungi) in the water. Samples were collected in sterile 250 ml glass bottles early in the morning. The tap supplying the house's main water was thoroughly cleaned and sterilized using an alcohol ignition method. After sterilization, the tap was turned on for 2 – 3 minutes to remove stagnant water. The sterile bottle was filled by opening the cap near the tap, ensuring to leave some space in the bottle to allow for shaking the sample to achieve uniform distribution of bacteria. Next, 2.0 – 3.0 ml of a 10% sodium thiosulfate solution was added to neutralize any residual chlorine. The necessary information was recorded on the bottle, and the bottles were stored in a refrigerated box for transport to the laboratory for testing (APHA, 2012).

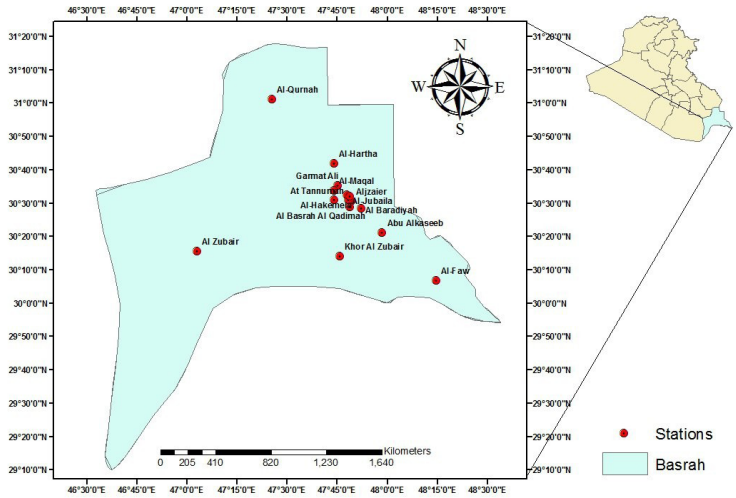

Figure 1. Map of study areas in Basrah governorate, Iraq

Table 1. Sites of collected samples

No.	Site of samples	The description of the sites	Number of tap water samples	Number of tank samples
1	Al Baradiyah	An urban area surrounded by farms	3	3
2	Aljzaier	An urban area located in the city center	3	3
3	Abu Al-Khaseeb	A rural area surrounded by rivers located south of the city	3	3
4	At Tannumah	A rural area surrounded by farms	3	3
5	Al Zubair	A residential area where there is no rivers	3	3
6	Al Basrah Al Qadimah	An urban area located in the city center	3	3
7	Garmat Ali	A rural area surrounded by rivers located north of the city	3	3
8	Al-Qurnah	A rural area surrounded by rivers located north of the city	3	3
9	Al-Hartha	A rural area surrounded by rivers located north of the city	3	3
10	Al-Faw	A residential area by the sea	3	3
11	Khor Al Zubair	A rural area surrounded by farms	3	3
12	Al-Jubaila	An urban area located in the city center	3	3
13	Al-Maqal	An urban area located by the river	3	3
14	Yaseen Khrebit	A residential area located west of the city	3	3
15	Al-Hakemia	A residential area surrounded by farms	3	3

2.2 Sample analysis

All collecting samples of tap water and household tanks were analyzed for the following microbial contamination according to standard guidelines APHA (APHA, 2012).

2.2.1 Detection of Total Bacterial Count (TBC)

The process was done using "Standard Method for the Examination of Water and Wastewater, 9222B, Membrane Filter Technique for Total Bacterial Count ". The samples were diluted by taking 1 mL of each water sample and add it to 9 mL of sterile distilled water. Make a series of dilutions from 10^{-1} to 10^{-6}. Then, 1 mL of each dilution of the water sample was filtered through a cellulose nitrate membrane filter (0.45 µm pore size; Sartorius, Germany). After the filtration process, each filter paper is transferred using sterile forceps to the solid nutrient medium and the medium is incubated at 37 °C for 24 hours to detect the total bacterial content on the surface of the paper.

2.2.2 Detection of Total coliform Bacteria

Total coliform bacteria counts were investigated using a filtration technique with a filtration unit containing a cellulose nitrate membrane filter (0.45 µm) according to "Standard Method for the Examination of Water and Wastewater, 9222B, Membrane Filter Technique for Coliforms"). The filter paper was placed on M-Endo Agar medium, which was then incubated at 37 °C for 24 hours.

2.2.3 Detection of Fecal coliform bacteria

Fecal coliform bacteria counts were investigated using a filtration technique with a filtration unit containing a cellulose nitrate membrane filter (0.45 µm pore size) according to "Standard Method for the Examination of Water and Wastewater, 9222B, Membrane Filter Technique for fecal Coliforms"). The filter paper was placed on M-FC Agar medium, which was then incubated in a water bath at 44.5 °C for 24 hours.

2.2.4 Detection of fungi

One mL of the final dilution was withdrawn and transferred to a sterile Petri dish. Potato dextrose agar medium was added to dish before it solidified. The dish was stirred to ensure homogenization. The dishes were then left to solidify and incubated at 25 °C. Three replicates of the sample were used.

The number of colonies on each plate was counted using the bacterial counting equation as follows:

$$\text{No. of colonies (CFUs) per 100 mL} = \frac{\text{No.of colonies}}{\text{Volume of filtered samples}} * \text{dilution} * 100$$

3. Results and Discussion

3.1 Results

3.1.1 Detection of Total Bacterial Count (TBC)

The results of the total bacterial count examination of tap water and tanks samples in some areas of the Basrah governorate are shown in Figure 2. The results indicated that all samples were contaminated with bacteria in large numbers. Samples from eight locations revealed significant bacterial contamination, both in tap water and storage tanks, while samples from 7 areas showed less contamination, though still in significant numbers. It is possible to calculate the number of bacteria in these samples, as shown in Table 2.

3.1.2 Detection of Total coliform Bacteria

The results of current study revealed that all samples were contaminated with total coliform bacteria at varying rates. Samples from 7 areas showed coliform bacteria contamination with numbers that were difficult to count, while samples from 8 areas showed significant contamination with varying numbers among the samples, as shown in Table 3.

Table 2. Detection of total bacterial count (TBC) in tap water samples and domestic tanks

No.	Site of samples	Tap water samples CFU/100 mL	Tank samples CFU/100 mL
1	Al Baradiyah	UC	UC
2	Aljzaier	UC	UC
3	Abu Al-Khaseeb	187	252
4	At Tannumah	UC	UC
5	Al Zubair	231	267
6	Al Basrah Al Qadimah	UC	UC
7	Garmat Ali	UC	UC
8	Al-Qurnah	38	89
9	Al-Hartha	294	UC
10	Al-Faw	UC	UC
11	Khor Al Zubair	189	272
12	Al-Jubaila	UC	UC
13	Al-Maqal	UC	UC
14	Yaseen Khrebit	112	182
15	Al-Hakemia	41	103

*UC: Uncountable colonies

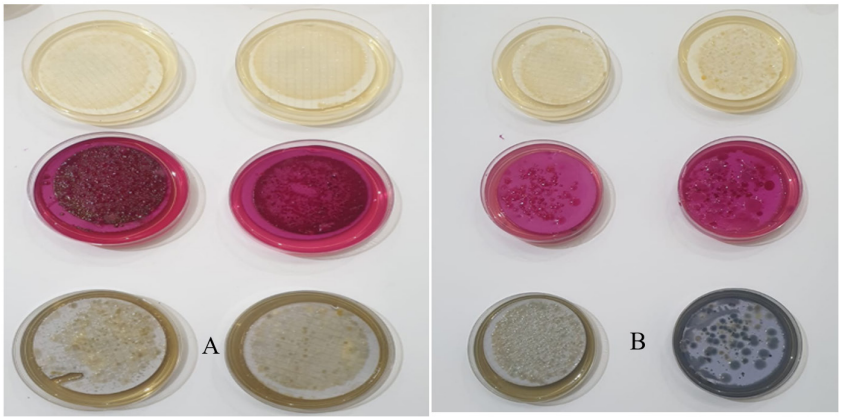

Figure 2. Bacterial contamination of tap water and domestic tanks in some areas of Basrah governorate (A) Microbial growth from tap water sample on nutrient agar plates, M-Endo Agar plates and M-FC Agar plates from 1 site showing bacterial contamination of sample, (B) Microbial growth from Tank sample on nutrient agar plates, M-Endo Agar plates and M-FC Agar plates from 3 site illustrating bacterial contamination of sample

Table 3. Detection of total coliform bacteria in tap water samples and domestic tanks

No.	Site of samples	Tap water samples CFU/100 mL	Tank samples CFU/100 mL
1	Al Baradiyah	UC	UC
2	Aljzaier	UC	UC
3	Abu Al-Khaseeb	89	143
4	At Tannumah	UC	UC
5	Al Zubair	78	122
6	Al Basrah Al Qadimah	UC	UC
7	Garmat Ali	106	172
8	Al-Qurnah	23	186
9	Al-Hartha	112	151
10	Al-Faw	UC	UC
11	Khor Al Zubair	72	94
12	Al-Jubaila	UC	UC
13	Al-Maqal	UC	UC
14	Yaseen Khrebit	66	90
15	Al-Hakemia	57	83

*UC: Uncountable colonies

3.1.3 Detection of Fecal coliform bacteria

The results of the investigation of fecal coliform bacteria in the studied samples showed that all water samples contained fecal coliform bacteria in large numbers that are difficult to count in many samples, as shown in Table 4. This indicates that all water samples are unfit for human use.

3.1.4 Detection of fungi

The results of the fungal examination, as shown in Table 5 and Figure 3, indicate the isolation and identification of fungi representing the anamorphic fungi from water samples. Most of the species belong to the genus *Aspergillus*, with the fungus *Aspergillus niger* being the dominant one, in addition to other fungal species isolated from some samples, but at a lower rate, such as *Penicillium* sp., *Fusarium* sp., and *candida* sp.

3.2 Discussion

Water serves as a medium for the spread and distribution of bacteria associated with humans. Contaminated water is containing opportunistic pathogenic bacteria poses health risks for consumers. To protect human health, it is essential to prevent bacterial contamination of water intended for consumption. Unprotected water sources can become contaminated through rainfall runoff, agricultural inputs, and the mixing of sewage effluents and wildlife feces, making them unsuitable for human consumption (Mulamattathil *et al.,* 2014). The poor quality of raw water supplied to water treatment plants and the lack of treatment procedures are responsible for the emergence of bacterial contamination and the failure to produce water free of pathogenic bacteria at these water treatment plants (Todd, 2020). Coliform bacteria are a type of bacteria that indicate contamination by human or animal feces. The bacteria have been isolated from drinking water and identified as coliform bacteria, which are considered pathogenic intestinal bacteria known to cause diarrhea in infants and children (Holcomb and Stewart, 2020).

The study revealed the presence of total coliforms, fecal coliforms, and total count bacteria in the investigated water samples, indicating water contamination, as some of these species serve as indicators of fecal contamination. These organisms may harbor potential pathogens, posing severe health risks to consumers, particularly immunocompromised individuals and children. The reduction in bacterial numbers in the treated water compared to raw water can be attributed to the treatment process. However, the presence of bacteria in the treated water still raises concerns, as they may carry potential pathogens. These health risks must be considered when distributing water, especially when the drinking water purification facility is located near sewage treatment and effluent disposal facilities

Table 4. Detection of fecal coliform bacteria in tap water samples and domestic tanks

No.	Site of samples	Tap water samples CFU/100 mL	Tank samples CFU/100 mL
1	Al Baradiyah	UC	UC
2	Aljzaier	UC	UC
3	Abu Al-Khaseeb	87	115
4	At Tannumah	UC	UC
5	Al Zubair	UC	UC
6	Al Basrah Al Qadimah	UC	UC
7	Garmat Ali	UC	UC
8	Al-Qurnah	UC	UC
9	Al-Hartha	70	91
10	Al-Faw	UC	UC
11	Khor Al Zubair	61	85
12	Al-Jubaila	UC	UC
13	Al-Maqal	UC	UC
14	Yaseen Khrebit	91	133
15	Al-Hakemia	42	48

*UC: Uncountable colonies

Table 5. Detection of fungi in tap water samples and domestic tanks

No.	Site of samples	Tap water samples	Tank samples
1	Al Baradiyah	*Aspergillus niger, Penicillium* sp.	*Aspergillus niger, Penicillium* sp., *Fusarium* sp.
2	Aljzaier	*A. niger*	*A. niger*
3	Abu Al-Khaseeb	*A. niger, candida* sp.	*A. niger, candida* sp.
4	AL-Tannumah	*A. niger*	*A. niger, Penicillum* sp.
5	Al Zubair	*A. niger*	*A. niger*
6	Al Basrah Al Qadimah	*A. niger, A. terreus,*	*A. niger, A. terreus, A. fumigatus, candida* sp.
7	Garmat Ali	*Candida* sp.	*A. niger, candida* sp.
8	Al-Qurnah	*A. niger*	*A. niger*
9	Al-Hartha	*A. niger, candida* sp.	*A. niger, Penicillium* sp., *candida* sp.
10	Al-Faw	*A. niger, Penicillium* sp., *candida* sp.	*A. niger, Penicillum* sp., *candida* sp.
11	Khor Al Zubair	*A. niger*	*A.niger*
12	Al-Jubaila	*A. niger*	*A. niger, Penicillium* sp.
13	Al-Maqal	*A. niger, A. terreus,*	*A. niger, candida* sp., *Fusarium* sp.
14	Yaseen Khrebit	*A. niger*	*A. niger*
15	Al-Hakemia	*A. niger*	*A. niger*

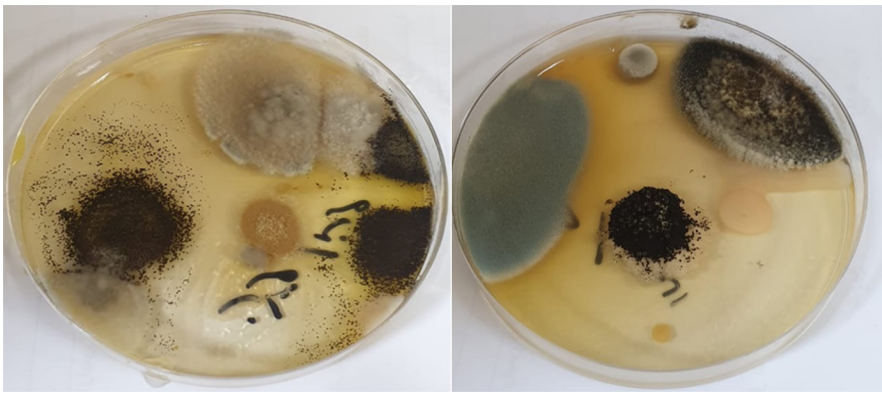

Figure 3. Fungal contamination of tap water and domestic tanks in some areas of Basrah governorate, identified based on the use of standard methods of morphological diagnosis

(Mulamattathil *et al.,* 2014; Chinfak *et al.,* 2023). Bacterial contamination of water, in terms of numbers and types of bacteria, is an important indicator of the quality of water and its suitability for any type of use, in addition to the interaction of various environmental factors such as temperature, which leads to an increase or decrease in microbial contamination.

The results of the current study showed that most water samples are not suitable for domestic use according to international standards, which specify allowable limits for each type of water, whether for drinking, bathing, or other uses (Mohammadpour *et al.,* 2024). It appears that the main reason for the presence of coliform bacteria and fecal coliform bacteria in water samples from different areas of Basrah governorate is the contamination of the water source supplied to the stations with sewage water. It was observed that the sewage water was not properly treated before being returned to the river, and thus it is transferred to the water filtration stations are serving the areas of Basrah governorate. Contamination of water treatment plants is associated with several factors, including

the inefficiency of the sedimentation process for removing suspended matter and silt from raw water. Additionally, inefficient filtration processes contribute to higher contamination rates. Furthermore, the moderate water temperatures in Basrah governorate promote the growth of pathogenic microorganisms, which explains the severe contamination is observed in the water samples.

Increasing the turbidity of raw water protects bacterial cells from the effects of disinfectants used in water sterilization (Garay *et al.,* 2021). Turbidity has been observed to increase significantly in the Shatt al-Arab River during the rainy season, raising the amount of mud and suspended matter in the river. This affects the efficiency of chlorine sterilization, as the bactericidal effect of chlorine requires contact with the surface of bacterial cells for a period of no less than 30 minutes. This contact does not occur in the presence of clay particles, which protect the bacterial cells.

The contamination of water samples with total coliforms, fecal coliforms, and total count bacteria was not limited to tap water; it was also found in bottled water sold in markets throughout Basrah governorate. This poses a significant health risk, as people often consume bottled water for drinking. Consequently, regulatory authorities must closely monitor and enforce appropriate water treatment procedures (Hillo, 2016; Al-Khafaji *et al.,* 2024).

The results of the fungal examination revealed the isolation and identification of several fungi, with most species belonging to the genus of *Aspergillus*. The widespread presence of this genus may be attributed to its ability to produce reproductive units that are resistant to environmental conditions, the ease with which these units spread in water, and the presence of highly effective enzymes. Numerous studies have demonstrated that *Aspergillus* is globally prevalent and has been isolated from various environments. It is particularly common in warm regions, with its reproductive units found in the air, soil, and water (Richardson and Rautemaa-Richardson, 2019).

The study revealed that both tap water and water from tanks in Basrah governorate are unsuitable and unsafe for human consumption. The presence of total bacterial count, coliform bacteria, fecal bacteria, other bacterial species and fungi in the tap water samples indicates a failure to adhere to established guidelines for disinfection and the infiltration of contaminated water. Furthermore, inadequate storage conditions promote bacterial growth to harmful levels. Therefore, there is an urgent need for stringent monitoring of water treatment plants and strict compliance with health protocols.

4. Conclusion

The current study conducted about the microbial content in tap water and household tanks samples by detecting the total bacterial content, total coliforms, fecal coliforms, and fungal contamination. The assessment of the microbial quality of tap water in the current study confirmed the presence of various microbial species including total bacterial count, total coliforms, fecal coliforms, and fungal species in all samples. The contamination of tap water and household tanks in Basrah governorate with various microorganisms results from several factors, including sewage contamination of water sources and inadequate treatment at water treatment plants. Microbial examination parameters showed severe contamination of 100% according to WHO standards in all tested water samples. This situation indicates that tap water in Basrah governorate is unsuitable for various domestic uses. Providing safe water and treating pollution requires government efforts to monitor water treatment plants and distribution networks, and conduct periodic inspections to ensure clean water reaches homes.

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References

Al-Jaberi ZA., Al-Abbawy DA. Assessing the Microbial Safety of Drinking Water in Basrah Province: A study of Three Water Treatment Plants. In IOP Conference Series: Earth and Environmental Science 2023; 1215(1): 012056

Al-Khafaji AM, Al-mansoory AF, Alyousif NA. Utilizing Bioflocculants Produced by Bacteria to Remediate Oil Contaminated Water. Pollution 2025; 11(2): 440-453. https://doi.org/10.22059/poll.2024.380806.2507.

Al Khafaji AM, Almansoory AF, Alyousif NA. Isolation, screening and molecular identification of bioflocculants–producing bacteria. Biodiversitas Journal of Biological Diversity 2023; 24(8): 4410-4417. DOI: 10.13057/biodiv/d240822.

Al Khafaji AM, Almansoory AF, Alyousif NA. Evaluation of bioflocculants produced by some bacteria and their use to remove artificial turbidity from water. Marsh Bulletin 2024; 19(2): 107-116.

Al-Khafaji SA, Alawadi WA, Altaee AM, Maki AA, Al-Shmailawi AH. Assessment of Reverse Osmosis Water and Some Types of Packaged Bottled Water in Basra City, Southern Iraq. Mesopotamian Journal of Marine Sciences 2024; 39(2): 215-226.

Almuktar S, Hamdan ANA, Scholz M. Assessment of the effluents of basra city main water treatment plants for drinking and irrigation purposes. Water 2020; 12(12): 3334. https://doi.org/10.3390/w12123334.

APHA. Standard Methods for the Examination of Water and Waste Water. 22nd Edition, American Public Health Association, American Water Works Association, Water Environment Federation. 2012.

Hillo NA. Bacteriological Assessment of some domestic bottled waters marketed in Basrah governorate, Iraq. Marsh Bulletin 2016; 11(2):125-134.

Babuji P, Thirumalaisamy S, Duraisamy K, Periyasamy G. Human health risks due to exposure to water pollution: a review. Water 2023; 15(14), 2532. https://doi.org/10.3390/w15142532.

Bănăduc D, Simić V, Cianfaglione K, Barinova S, Afanasyev S, Öktener A, McCall G, Simi´c S, Curtean-Bănăduc A. Freshwater as a sustainable resource and generator of secondary resources in the 21st century: Stressors, threats, risks, management and protection strategies, and conservation approaches. International Journal of Environmental Research and Public Health 2022; 19(24): 16570. https://doi.org/10.3390/ijerph192416570.

Chinfak N, Charoenpong C, Sompongchaiyakul P, Wu Y, Supcharoen R, Zhang J. Environmental factors influencing the distribution of fecal coliform bacteria in Bandon Bay, Thailand. Regional Studies in Marine Science 2023; 68: 103277. https://doi.org/10.1016/j.rsma.2023.103277.

Garay DFA, Voltolini LC, Bastos RG, Souza CF. Effect of turbidity on ultraviolet disinfection of domestic wastewater for agricultural reuse. Revista Ambiente and Água 2021; 16(6), e2766. doi:10.4136/ambi-agua.2766.

Haldar K, Kujawa-Roeleveld K, Hofstra N, Datta DK, Rijnaarts H. Microbial contamination in surface water and potential health risks for peri-urban farmers of the Bengal delta. International journal of hygiene and environmental health 2022; 244: 114002. https://doi.org/10.1016/j.ijheh.2022.114002.

Holcomb DA, Stewart JR. Microbial indicators of fecal pollution: recent progress and challenges in assessing water quality. Current environmental health reports 2020; 7(3): 311-324. doi: 10.1007/s40572-020-00278-1.

Lin L, Yang H, Xu X. Effects of water pollution on human health and disease heterogeneity: a review. Frontiers in environmental science 2022; 10, 880246. https://doi.org/10.3389/fenvs.2022.880246.

Mahdi E, Al-Abbawy DH. Removal Efficiency, Accumulation and Toxicity of Nickel and Lead using *Ceratophyllum demersum*. International Journal of advanced research in Science, Engineering and Technology 2019; 6(1).

Mohammadpour A, Gharehchahi E, Gharaghani MA, Shahsavani E, Golaki M, Berndtsson R, Khaneghah AM, Hashemi H, Abolfathi S. Assessment of drinking water quality and identifying pollution sources in a chromite mining region. Journal of Hazardous Materials 2024; 480: 136050. https://doi.org/10.1016/j.jhazmat.2024.136050.

Mohammad AJ, Alyousif NA, Al-Mosawi UAS, Al-Hejuje MM. Assessment of water quality supplies in some areas of Basrah Governorate, Iraq. Ecology Environment and Conservation 20121; 27(1): 408-413.

Mulamattathil SG, Bezuidenhout C, Mbewe M, Ateba CN. Isolation of environmental bacteria from surface and drinking water in Mafikeng, South Africa, and characterization using their antibiotic resistance profiles. Journal of pathogens 2014; 2014(1): 371208. https://doi.org/10.1155/2014/371208.

Nallakukkala S, Lal B. Seawater and produced water treatment via gas hydrate. Journal of Environmental Chemical Engineering 2021; 9(2), 105053. https://doi.org/10.1016/j.jece.2021.105053.

Richardson M, Rautemaa-Richardson R. Exposure to *Aspergillus* in home and healthcare facilities' water environments: focus on biofilms. Microorganisms 2019; 7(1): 7. https://doi.org/10.3390/microorganisms7010007.

Richiardi L, Pignata C, Fea E, Bonetta S, Carraro E. Are indicator microorganisms predictive of pathogens in water?. Water 2023; 15(16): 2964. https://doi.org/10.3390/w15162964.

Saraswat RK, Verghesep S, Pachauri T. Water quality assessment based on physico-chemical and biological analysis of Khari River. Materials Today: Proceedings 2022; 52: 1354-1360. https://doi.org/10.1016/j.matpr.2021.11.083

Todd EC. Waterborne diseases and wastewater treatment in Iraq. Journal of Food Protection 2024; 87(1): 100204. https://doi.org/10.1016/j.jfp.2023.100204.