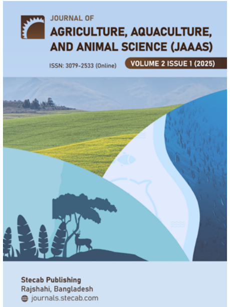

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Research Article

Bacteriological Contamination in Indoor Swimming Pools: Prevalence and Pathogen Identification in Wasit, Iraq

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About Article

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ABSTRACT

Since tainted water may spread a number of waterborne illnesses, water quality is an important consideration in preserving public health. The pollution of swimming pools, a common characteristic of recreational facilities, especially in the warmer months, is one of the main issues. The purpose of the research was to find out how often bacterial contamination was in indoor swimming pool settings and water. During June and July of 2024, a total of 100 swab samples were gathered evenly from the water, pool ladders, pool margins, and changing areas of several swimming pools in Wasit province, Iraq. Following their independent cultivation on three different medium (Blood Agar, Eosin Methylene Blue Agar, and MacConkey Agar), the swabs were purified and identified using biochemical testing and morphological traits. In all, 37% of swab samples included different types of bacteria, which were detected in water (12%), pool ladders (44%), changing rooms (36%), and pool margins (56%). Following that, 68 (37.99%), 39 (21.79%), 45 (25.14%), and 27 (15.08%) bacterial isolates were found in water, changing areas, pool borders, and pool ladders, respectively. Twelve bacterial species were found in changing rooms, however *Escherichia coli* and *Klepsellia aerogenes* were the most important. Eleven bacterial species were identified in pool borders; notable increases were seen in Vibrio cholera, Aeromonus hydrophila, Escherichia coli, and Klepsellia pneumonia. Ten bacterial species, including Vibrio cholera, Escherichia coli, and Klepsellia pneumonia, were identified in relation to the pool ladders. Along with Vibrio cholera, Aeromonus hydrophila, Pseodomonus argenosa, Proteus mirabrillis, and, less significantly, Klepsellia pneumonia, Acintopacter baumannii, Klepsellia aerogenes, Proteus vulgaris, Salmonella epidermidis, Streptococcus faecalis, Anteropacter cloacae, Citropecter frndii, Edwardsiella tarda, and *Serratia liquefaciens*, 15 species of bacteria were identified in relation to water. According to the current study's findings, swimming pools are a source of diverse bacteria that swimmers may get, leading to a variety of diseases, including skin infections. Therefore, in order to reduce the danger of bacterial contamination in swimming pools, we recommended the adoption of thorough water quality monitoring programs, the use of cutting-edge diagnostic tools to detect and track possible pathogens, and the use of efficient disinfection tactics.

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1. INTRODUCTION

Water is an essential resource for sustaining the life, and its contamination poses a significant threat to human health and the environment (Mishra, 2023). The prevalence of water-borne pollutants (physical, chemical and biological) has become a global concern since over one billion people lack access to clean water sources (Manetu & Karanja, 2021). One of the most widespread water quality issues is pathogen loading through the deposition of sewage and untreated wastewater, which leading degradation of aquatic ecosystems, and spreading of infectious diseases, with accumulation of hazardous substances such as heavy metals that can result in chronic poisoning and a variety of health problems (Akpor & Muchie, 2011; Karri *et al.*, 2021; Jan *et al.*, 2022). To address the issue of water contamination, a multifactorial approach is required involving regular monitoring, effective treatment technologies, and the implementation of stricter regulations to control the discharge of pollutants into water bodies (Altenburger *et al.*, 2015; Brack *et al.*, 2017).

2. LITERATURE REVIEW

Swimming pools are ubiquitous features of many recreational facilities, providing a refreshing and enjoyable environment for people of all ages to engage in physical activity, socialize and beat the heat during the warmer months (Anderson *et al.*, 2014; Pangrazi & Beighle, 2019; Chaúque *et al.*, 2022). However, the very nature of swimming pools with their high bather loads and intermittent water circulation can make them susceptible to bacterial contamination posing potential health risks to swimmers (Barna & Kádár, 2012; Bonadonna & La Rosa, 2019). One of the primary concerns regarding bacterial contamination is the presence of pathogenic microorganisms that can cause a wide-range of infections even death (Okafor, 2011; Stec *et al.*, 2022). Furthermore, the formation of biofilms by bacterial communities within the pool and existence of wild animals such as birds, dogs and cats can act as a source of contamination and enhance their ability to resist disinfection (Guida *et al.*, 2016; Khan *et al.*, 2016; Nguyen *et al.*, 2024). Additionally, investigations have been revealed the presence of multi-drug resistant bacteria on inanimate surfaces within the pool environment highlighting the potential cross-contamination and needing to rigorous cleaning and disinfection protocols (Cantón *et al.*, 2013; Kramer & Assadian, 2014; Koeck *et al.*, 2018; Ekowati, 2019).

In Iraq, the numbers of swimming pools have been increased significantly in last 20 years. Nonetheless, almost national studies have focused on water hygiene or water quality (Khalaf *et al.*, 1992; Aenab & Singh, 2012), and data described the microbiological characteristics of public swimming pools remain very rare of old (Ali *et al.*, 2009). Hence, the current study was conducted to investigate the almost prevalent bacterial contamination in indoor swimming pools in Baghdad and Wasit provinces (Iraq).

3. MATERIALS AND METHODS

3.1. Ethical approval

This study licensed by the Scientific Committee of the Department of Biology, College of Education for Pure Sciences (University of Wasit).

3.2. Preparation of culture media and transport broth

In this study, three culture media (Blood Agar, Eosin Methylene Blue Agar and MacConkey Agar) and one transport broth, Brain-Heart Infusion (BHI), in addition to seven biochemical tests (catalase, coagulase, gas and indol production, sugar fermentation and urease activity), and Gram stain were prepared according to their manufacturers' instructions (HiMedia, India).

3.3. Samples

A total of 100 swab samples were collected from the changing rooms (total no=25), pool edges (total no=25), pool ladders (total no=25) and water (total no=25) of various indoor swimming pools found in Wasit province (Iraq) during June and July (2024). The swabs were kept in tubes containing the BHI broth and transported to the laboratory under cooled condition to be cultured as soon as possible.

3.4. Bacteriological examination

Under aseptic conditions, the swabs were streaked separately on the prepared three media, and incubated at 37°C for 24 hours, and the grown colonies were re-cultured additionally for purification (Ibraheim *et al.*, 2023).

3.5. Morphological and biochemical characterization

Initially, all bacterial isolates were used to preparation the Gram stained slides that tested by light microscope (Zeiss, Germany) at a magnification of 1000X to identify their morphological characteristics. Finally, biochemical testing was done to the species of study isolates (Jasim *et al.*, 2024).

3.6. Diagnosis of bacterial species via VITEK2 technology

The species of bacterial isolates were identified in current study using the VITEK2 Compact System (bioMérieux, France). Briefly, bacterial suspensions were employed in 45% sterile NaCl as similar to McFarland Standards ($0.5x10^8$ CFU/ml).

3.7. Statistical analysis

The t-test and One Way-Analysis of Variance (ANOVA) in the GraphPad Prism Software (version 8.0.2) was applied to detect significant differences between study values (mean ± standard error) at $p<0.05$ (Gharban, 2024).

4. RESULTS AND DISCUSSION

4.1. Results

Our findings revealed that overall 37% (37/100) of swab samples were contaminated with various species of bacteria (Figure 1). Significantly ($p<0.0283$, CI = 7.430 to 66.57, $r2 = 0.8409$), pool edges were showed the higher rate of contamination [56% (14/25)] while water having the lower one [12% (3/25)] when compared to values of changing rooms [36% (9/25)] and pool ladders [44% (11/25)], (Figure 2).

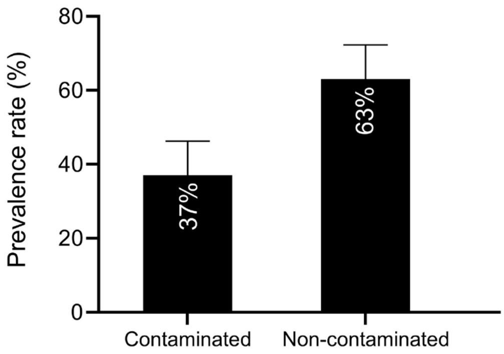

Figure 1. Total results of testing the environments and water of swimming pools (total No=100)

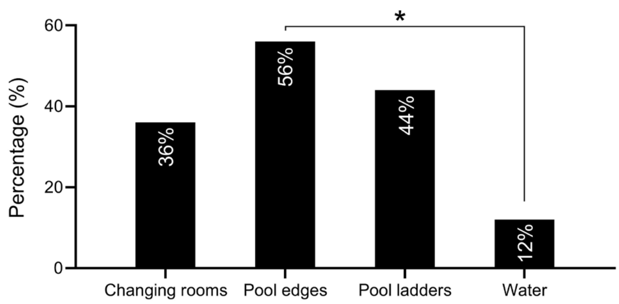

Figure 2. Distribution of contaminated samples according to type of swab sample

Subsequently, significant increase [p<0.0138, CI = 9.697 to 40.30, r2 = 0.9001] in number of bacterial isolates was identified in water [68 (37.99%)] whereas the lowest was observed in pool ladders [27 (15.08%)] in comparison to changing rooms [39 (21.79%)] and pool edges [45 (25.14%)], (Figure 3).

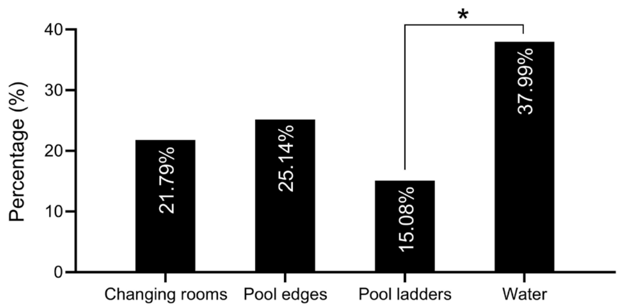

Figure 3. Number of bacterial isolates obtained from the environments and water of swimming pools

In changing rooms, a total of 12 species of bacteria was reported; in which, significant prevalence was seen in *Escherichia coli* (28.21%) as well as in *Klepsellia aerogenes* (12.82%) when compared to other bacterial species including *Pseodomonus argenosa* (10.26%), *Staphylococcus aureus* (10.26%), *Vibrio cholera* (10.26%), *Proteus mirabrillis* (7.69%), *Aeromonus hydrophila* (5.13%), *Klepsellia pneumonia* (5.13%), *Acintopacter baumannii* (2.56%), *Proteus vulgaris* (2.56%), *Salmonella epidermidis* (2.56%), and *Streptococcus faecalis* (2.56%), (Table 1).

Table 1. Bacterial species identified changing rooms of swimming pools

Species	No.	%	
Acintopacter baumannii	1	2.56	
Aeromonus hydrophila	2	5.13	
Escherichia coli	11	28.21 **	
Klepsellia aerogenes	5	12.82 *	
Klepsellia pneumonia	2	5.13	p<0.0038 CI = 2.189 to 9.576 r^2 = 0.4160
Proteus mirabrillis	3	7.69	
Proteus vulgaris	1	2.56	
Pseodomonus argenosa	4	10.26	
Salmonella epidermidis	1	2.56	
Staphylococcus aureus	4	10.26	
Streptococcus faecalis	1	2.56	
Vibrio cholera	4	10.26	

In pool edges, 11 bacterial species were recorded; in which, significant increases were seen in *Klepsellia pneumonia* (20%), *Escherichia coli* (17.78%), as well as in *Aeromonus hydrophila* (13.33%), *Vibrio cholera* (13.33%), *Proteus mirabrillis* (11.11%) in comparison to other bacterial species; *Acintopacter baumannii* (6.67%), *Klepsellia aerogenes* (4.44%), *Proteus vulgaris* (4.44%), *Salmonella epidermidis* (4.44%), *Serratia liquefaciens* (2.22%), and *Staphylococcus aureus* (2.22%), (Table 2).

Table 2. Bacterial species identified pool edges of swimming pools

Species	No.	%	
Acintopacter baumannii	3	6.67	
Aeromonus hydrophila	6	13.33 *	
Escherichia coli	8	17.78	
Klepsellia aerogenes	2	4.44	
Klepsellia pneumonia	9	20 **	p<0.0023 CI = 2.431 to 9.331 r^2 = 0.4494
Proteus mirabrillis	5	11.11	
Proteus vulgaris	2	4.44	
Salmonella epidermidis	2	4.44	
Serratia liquefaciens	1	2.22	
Staphylococcus aureus	1	2.22	
Vibrio cholera	6	13.33 *	

Table 3. Bacterial species identified pool ladders of swimming pools

Species	No.	%	
Aeromonus hydrophila	1	3.7	
Escherichia coli	5	18.52 *	
Klepsellia pneumonia	4	14.81	
Proteus mirabrillis	2	7.41	p<0.0099 CI = 1.620 to 10.14 r^2 = 0.3485
Proteus vulgaris	1	3.7	
Pseodomonus argenosa	1	3.7	
Roatinolia terrigena	1	3.7	
Salmonella epidermidis	3	11.11	
Staphylococcus aureus	1	3.7	
Vibrio cholera	8	29.63 **	

Regarding water, 15 species of bacteria were diagnosed; most significantly including *Escherichia coli* (19.12%) in addition to *Vibrio cholera* (13.24%), *Aeromonus hydrophila* (10.29%), *Pseodomonus argenosa* (10.29%), *Proteus mirabrillis* (8.82%), and less significantly in *Klepsellia pneumonia* (7.35%), *Acintopacter baumannii* (5.88%), *Klepsellia aerogenes* (5.88%), *Proteus vulgaris* (4.41%), *Salmonella epidermidis* (4.41%), *Streptococcus faecalis* (4.41%), *Anteropacter cloacae* (1.47%), *Citropecter frndii* (1.47%), *Edwardsiella tarda* (1.47%), and *Serratia liquefaciens* (1.47%), (Table 4).

Table 4. Bacterial species identified water of swimming pools

Species	No.	%	
Acintopacter baumannii	4	5.88	
Aeromonus hydrophila	7	10.29	
Anteropacter cloacae	1	1.47	
Citropecter frndii	1	1.47	
Edwardsiella tarda	1	1.47	
Escherichia coli	13	19.12 ***	
Klepsellia aerogenes	4	5.88	p<0.0003 CI = 3.208 to 8.555 r^2 = 0.5761
Klepsellia pneumonia	5	7.35 *	
Proteus mirabrillis	6	8.82	
Proteus vulgaris	3	4.41	
Pseodomonus argenosa	7	10.29	
Salmonella epidermidis	3	4.41	
Serratia liquefaciens	1	1.47	
Streptococcus faecalis	3	4.41	
Vibrio cholera	9	13.24 **	

4.2. Discussion

One of the most prevalent environmental issues worldwide is water pollution, which is a global cry to enhance people's lives and opportunities (Muhammed & Abubakar, 2022). Since many people use public indoor swimming pools on a daily basis, they may be contaminated with bacteria and other infectious agents, including a wide range of unicellular microorganisms (Papadopoulou *et al.*, 2008; Gerba & Pepper, 2019). In addition to their potential to spread either directly or indirectly, bacteria are quite common in the environment and may quickly colonize, divide, and/or be found in nutrients, air, soil, and water (Dugan, 2022). 37% of the swab samples in this research included different types of bacteria, which were detected in the water (12%), pool ladders (44%), changing rooms (36%), and pool margins (56%). Following that, 68 (37.99%), 39 (21.79%), 45 (25.14%), and 27 (15.08%) bacterial isolates were found in water, changing areas, pool borders, and pool ladders, respectively. Twelve bacterial species were found in changing rooms, however *Escherichia coli* and *Klepsellia aerogenes* were the most important. Eleven bacterial species were identified in pool borders; notable increases were seen in Vibrio cholera, Aeromonus hydrophila, Escherichia coli, and Klepsellia pneumonia. Ten bacterial species, including Vibrio cholera, Escherichia coli, and Klepsellia pneumonia, were identified in relation to the pool ladders. Along with Vibrio cholera, Aeromonus hydrophila, Pseodomonus argenosa, Proteus mirabrillis, and, less significantly, Klepsellia pneumonia, Acintopacter baumannii, Klepsellia aerogenes, Proteus vulgaris, Salmonella epidermidis, Streptococcus faecalis, Anteropacter cloacae, Citropecter frndii, Edwardsiella tarda, and *Serratia liquefaciens*, 15 species of bacteria were identified in relation to water. According to our results, the top bacterial species found in swimming pool surroundings and water were Escherichia coli, Klepsellia spp. (K. aerogenes and K. pneumonia), and Vibrio cholera. According to Van Elsas *et al.* (2011) and Loayza *et al.* (2020), *Escherichia coli* is an intestinal pathogen that is spread from human or animal excrement to vulnerable hosts by contact with food and environmental compartments (water, surfaces, soil, hands, and flies). Since the presence of E. coli in water is often linked to an elevated risk of both enteric infections and diarrheal disorders, this bacterium is employed as an indicator to investigate the causes and outcomes of fecal pollution in the environment (Hunter, 2003; Gomes *et al.*, 2016; Ercumen *et al.*, 2017).

After a trailer park pool party, Friedman *et al.* (1999) found a cluster of gastrointestinal disorders, including one incidence of hemolytic-uremic syndrome and one culture-confirmed E. coli infection. Due to the fact that swimming pools are linked to a number of outbreaks because of the relative susceptibility of E. coli to sufficient levels of free chlorine, a report published in the United Kingdom details the investigation of an outbreak connected to a local leisure center pool and offers suggestions regarding the safe management of such facilities (Verma *et al.*, 2007).

Some bacteria are resistant to sodium hypochlorite, which is used to disinfect pools and is thought to be an opportunist microbe that causes various diseases, according to Rasti *et al.* (2012). These bacteria should not be disregarded when assessing the water quality of swimming pools, even if they are not thought to pose a serious risk and do not directly cause diseases in people (Purohit *et al.*, 2020; Nowicki *et al.*, 2021). Swimming pools may contain microorganisms linked to swimmers, such as fecal contamination of the water, unintentional fecal release or residual fecal material on bodies, and non-fecal shedding such as vomit, mucous, saliva, skin, mouth, and upper respiratory tract contamination, according to Ghasemi *et al.* (2019). According to earlier research, some bacteria may lead to a number of infections or illnesses affecting the respiratory, skin, or central nervous systems (Nichols, 2006; Papadopoulou *et al.*, 2008; WHO, 2009). The quality of pool waters during the working day has also been studied. According to some researchers, young children make up the majority of swimmers on weekends and holidays, so water sampling would be more effective during these periods (Fantuzzi *et al.*, 2010; Lévesque *et al.*, 2015; Carter *et al.*, 2019).

5. CONCLUSIONS

According to the current study's findings, swimming pools are a source of diverse bacteria that swimmers may get, leading to a variety of diseases, including skin infections. Therefore, in order to reduce the danger of bacterial contamination in swimming pools, we recommended the adoption of thorough water quality monitoring programs, the use of cutting-edge diagnostic tools to detect and track possible pathogens, and the use of efficient disinfection tactics.

REFERENCES

Aenab, A. M., & Singh, S. K. (2012). Critical assessment of environmental quality of Baghdad, Iraq. *Journal of Environmental Engineering, 138*(5), 601-606.

Akpor, O. B., & Muchie, B. (2011). Environmental and public health implications of wastewater quality. *African Journal of Biotechnology, 10*(13), 2379-2387.

Ali, L. A., Shekha, Y. A., & Toma, J. J. (2009). Determinants of the microbiological characteristics of Erbil city public swimming pools. *Journal of Duhok University, 12*(1), 1-13.

Altenburger, R., Ait-Aissa, S., Antczak, P., Backhaus, T., Barceló, D., Seiler, T. B., & Brack, W. (2015). Future water quality monitoring—Adapting tools to deal with mixtures of pollutants in water resource management. *Science of the total environment, 512*, 540-551.

Anderson, A. R., Ramos, W. D., & Middlestadt, S. E. (2014). A narrative investigation into dimensions of experience at an outdoor aquatic facility: A pool is more than a place to swim. *International Journal of Aquatic Research and Education, 8*(2), 4.

Barna, Z., & Kádár, M. (2012). The risk of contracting infectious diseases in public swimming pools: a review. *Annali dell'Istituto superiore di sanita, 48*, 374-386.

Bonadonna, L., & La Rosa, G. (2019). A review and update on waterborne viral diseases associated with swimming pools. *International journal of environmental research and public health, 16*(2), 166.

Brack, W., Dulio, V., Ågerstrand, M., Allan, I., Altenburger, R., Brinkmann, M., & Vrana, B. (2017). Towards the review of the European Union Water Framework Directive: recommendations for more efficient assessment and management of chemical contamination in European surface water resources. *Science of the Total Environment, 576*, 720-737.

Cantón, R., Horcajada, J. P., Oliver, A., Garbajosa, P. R., & Vila, J. (2013). Inappropriate use of antibiotics in hospitals: the complex relationship between antibiotic use and antimicrobial resistance. *Enfermedades infecciosas y microbiologia clinica, 31*, 3-11.

Carter, R. A., Allard, S., Croué, J. P., & Joll, C. A. (2019). 500 days of swimmers: the chemical water quality of swimming pool waters from the beginning. *Environmental Science and Pollution Research, 26*, 29110-29126.

Chaúque, B. J. M., Dos Santos, D. L., Anvari, D., & Rott, M. B. (2022). Prevalence of free-living amoebae in swimming pools and recreational waters, a systematic review and meta-analysis. *Parasitology Research, 121*(11), 3033-3050.

Dugan, P. R. (2022). Bacteria. In *Infection, Resistance, and Immunity, Second Edition* (pp. 283-318). Routledge.

Ekowati, Y. (2019). *Protection of public health from microbial and chemical hazards in swimming pool environments.* CRC Press.

Ercumen, A., Pickering, A. J., Kwong, L. H., Arnold, B. F., Parvez, S. M., Alam, M., & Colford Jr, J. M. (2017). Animal feces contribute to domestic fecal contamination: evidence from E. coli measured in water, hands, food, flies, and soil in Bangladesh. *Environmental science and technology, 51*(15), 8725-8734.

Fantuzzi, G., Righi, E., Predieri, G., Giacobazzi, P., Mastroianni, K., & Aggazzotti, G. (2010). Prevalence of ocular, respiratory and cutaneous symptoms in indoor swimming pool workers and exposure to disinfection by-products (DBPs). *International journal of environmental research and public health, 7*(4), 1379-1391.

Friedman, M. S., Roels, T., Koehler, J. E., Feldman, L., Bibb, W. F., & Blake, P. (1999). *Escherichia coli* O157: H7 outbreak associated with an improperly chlorinated swimming pool. *Clinical Infectious Diseases, 29*(2), 298-303.

Gerba, C. P., & Pepper, I. L. (2019). Microbial contaminants. *Environmental and pollution science* (pp. 191-217).

Gharban, H. A. (2024). First genotyping confirmation of Pichia kudriavzevii in subclinically mastitic cows, Iraq: Fungal subclinical mastitis. *Revista de Ciências Agroveterinárias, 23*(3), 417-424.

Ghasemi, F., Hatam, G. R., Zaravar, F., Mardaneh, J., Jafarian, H., Abbasi, P., & Badiee, P. (2019). Investigation of the physical, chemical characteristics and microbial contamination of the indoor swimming pools. *Turkiye Parazitol Derg, 43*(3), 130-134.

Gomes, T. A., Elias, W. P., Scaletsky, I. C., Guth, B. E., Rodrigues, J. F., Piazza, R. M., & Martinez, M. B. (2016). Diarrheagenic escherichia coli. *Brazilian journal of microbiology, 47*, 3-30.

Guida, M., Di Onofrio, V., Gallè, F., Gesuele, R., Valeriani, F., Liguori, R., & Liguori, G. (2016). Pseudomonas aeruginosa in swimming pool water: evidences and perspectives for a new control strategy. *International journal of environmental research and public health, 13*(9), 919.

Hunter, P. R. (2003). Drinking water and diarrhoeal disease due to Escherichia coli. *Journal of water and health, 1*(2), 65-72.

Ibraheim, H. K., Fayez, R. A., Jasim, A. S., & Gharban, H. A. (2023). Role of nuc gene in *Staphylococcus aureus* to phagocytic activity in different cattle infections. *Open Veterinary Journal, 13*(8), 1021-1026.

Jan, I., Ahmad, T., Wani, M. S., Dar, S. A., Wani, N. A., Malik, N. A., & Tantary, Y. R. (2022). Threats and consequences of untreated wastewater on freshwater environments. In *Microbial consortium and biotransformation for pollution decontamination* (pp. 1-26). Elsevier.

Jasim, A. S., Mohammed, A. L., Abbas, W. H., Ibraheim, H. K., & Gharban, H. A. (2024). Identification of blaOXA-23 gene in resistant Pseudomonas aeruginosa strains isolated from cows and humans in Basra province, Iraq. *Veterinary World, 17*(7), 1629.

Karri, R. R., Ravindran, G., & Dehghani, M. H. (2021). Wastewater—sources, toxicity, and their consequences to human health. In *Soft computing techniques in solid waste and wastewater management* (pp. 3-33). Elsevier.

Khalaf, S. H., Talec, A. Y., & Al-Bahawi, N. E. (1992). Water hygiene of swimming pools in Mosul City, Iraq. *Journal of Environmental Science and Health Part A, 27*(4), 1021-1031.

Khan, S., Beattie, T. K., & Knapp, C. W. (2016). Relationship between antibiotic-and disinfectant-resistance profiles in bacteria harvested from tap water. *Chemosphere, 152*, 132-141.

Koeck, D. E., Huber, S., Hanifi, N., Köster, M., Schierling, M. B., & Höller, C. (2018). Occurrence of antibiotic-resistant bacteria in therapy pools and surrounding surfaces. *International Journal of Environmental Research and Public Health, 15*(12), 2666.

Kramer, A., & Assadian, O. (2014). Survival of microorganisms on inanimate surfaces. *Use of biocidal surfaces for reduction of healthcare acquired infections*, 7-26.

Lévesque, B., Vézina, L., Gauvin, D., & Leroux, P. (2015). Investigation of air quality problems in an indoor swimming pool: a case study. *Annals of Occupational Hygiene, 59*(8), 1085-1089.

Loayza, F., Graham, J. P., & Trueba, G. (2020). Factors obscuring the role of E. coli from domestic animals in the global antimicrobial resistance crisis: an evidence-based review. *International journal of environmental research and public health, 17*(9), 3061.

Manetu, W. M., & Karanja, A. M. (2021). Waterborne disease risk factors and intervention practices: a review. *Open Access Library Journal, 8*(5), 1-11.

Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies, 4*(3), 1-78.

Muhammed, Z., & Abubakar, I. R. (2022). Improving the quality of life of urban communities in developing countries. In *Responsible Consumption and Production* (pp. 357-370). Cham: Springer International Publishing.

Nguyen, H. K., Jones, P. J., Kendal, D., Powell, S. M., & Flies, E. J. (2024). Wildlife microbiomes and the city: a systematic review of urban impacts on wildlife bacterial communities. *Microbiota and Host, 2*(1).

Nichols, G. (2006). Infection risks from water in natural and man-made environments. *Eurosurveillance, 11*(4), 1-2.

Nowicki, S., Delaurent, Z. R., de Villiers, E. P., Githinji, G., & Charles, K. J. (2021). The utility of *Escherichia coli* as a contamination indicator for rural drinking water: Evidence from whole genome sequencing. *PLoS One, 16*(1), e0245910.

Okafor, N. (2011). Disease transmission in water. *Environmental microbiology of aquatic and waste systems*, 189-214.

Pangrazi, R. P., & Beighle, A. (2019). *Dynamic physical education for elementary school children.* Human Kinetics Publishers.

Papadopoulou, C., Economou, V., Sakkas, H., Gousia, P., Giannakopoulos, X., Dontorou, C., & Leveidiotou, S. (2008). Microbiological quality of indoor and outdoor swimming pools in Greece: investigation of the antibiotic resistance of the bacterial isolates. *International journal of hygiene and environmental health, 211*(3-4), 385-397.

Purohit, M., Diwan, V., Parashar, V., Tamhankar, A. J., & Lundborg, C. S. (2020). Mass bathing events in River Kshipra, Central India-influence on the water quality and the antibiotic susceptibility pattern of commensal E. coli. *Plos one, 15*(3), e0229664.

Rasti, S., Assadi, M. A., Iranshahi, L., Saffari, M., Gilasi, H. R., & Pourbabaee, M. (2012). Assessment of microbial contamination and physicochemical condition of public swimming pools in Kashan, Iran. *Jundishapur Journal of Microbiology, 5*(3), 450-455.

Stec, J., Kosikowska, U., Mendrycka, M., Stępień-Pyśniak, D., Niedźwiedzka-Rystwej, P., Bębnowska, D., & Grywalska,

E. (2022). Opportunistic pathogens of recreational waters with emphasis on antimicrobial resistance—a possible subject of human health concern. *International Journal of Environmental Research and Public Health, 19*(12), 7308.

Van Elsas, J. D., Semenov, A. V., Costa, R., and Trevors, J. T. (2011). Survival of *Escherichia coli* in the environment: fundamental and public health aspects. *The ISME journal, 5*(2), 173-183.

Verma, A., Bolton, F. J., Fiefield, D., Lamb, P., Woloschin, E., Smith, N., & McCann, R. (2007). An outbreak of E. coli O157 associated with a swimming pool: an unusual vehicle of transmission. *Epidemiology and Infection, 135*(6), 989-992.

WHO (World Health Organization), (2009). Addendum to the WHO guidelines for safe recreational water environments. *Coastal and fresh waters: list of agreed updates* (volume 1).