Assessing public health implications of hospital wastewater discharge into urban river ecosystems: A Case Study of Aligarh

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This study investigates the public health risks associated with hospital wastewater (HWW) in Aligarh, focusing on microbial contamination and antibiotic-resistant bacteria. Conducted from January to June 2024, the researchers analyzed 32 samples, including 21 drinking water sources (17 handpumps and 4 reverse osmosis systems) and 11 sewage samples. The findings revealed concerning water quality issues, with pH and total dissolved solids (TDS) exceeding acceptable limits in many samples. Faecal coliform counts were alarmingly high, rendering two-thirds of the drinking water sources unfit for consumption. Among the 44 identified bacterial colonies, 39 were assessed for antibiotic susceptibility, revealing that 14 (over one-third) were carbapenem-resistant, highlighting the growing threat of antimicrobial resistance. Additionally, analysis of 1,128 suspected hepatitis A and E cases showed 143 positives, including 23 co-infections, while only 40 of 901 suspected typhoid cases were confirmed. These results underscore the urgent need for improved wastewater management and public health interventions. By implementing on-site treatment systems and community health initiatives, Aligarh can reduce the risks posed by HWW discharge, ultimately safeguarding public health and enhancing the sustainability of local water resources and ecosystems.

Introduction

Hospital wastewater (HWW) is generated from patient care, medical procedures, and laboratory operations within healthcare facilities. It contains a unique mixture of pollutants, including pharmaceuticals, pathogens, heavy metals, disinfectants, and various chemical compounds, making it distinct and potentially more hazardous compared to other types of wastewater. The presence of antimicrobial or antibiotic-resistant microorganisms in HWW poses significant public health risks (Kümmerer, 2009; Verlicchi et al., 2010).

Blackwater, rich in diverse microorganisms, primarily originates from fecal matter. These microorganisms can be pathogenic and may exhibit antimicrobial resistance, complicating wastewater treatment processes and posing threats to human health and the environment (Gao et al., 2012). Effective management of HWW is crucial to mitigate these risks and protect water resources.

Mitigation strategies for HWW include advanced treatment processes such as membrane bioreactors, advanced oxidation processes, and constructed wetlands, which can effectively reduce the load of hazardous contaminants (Zhang & Farahbakhsh, 2007). Implementing stringent regulations and promoting best practices in waste management within healthcare facilities are also essential steps towards minimizing the environmental impact of HWW (Kümmerer et al., 2019).

Urban rivers provide essential ecosystem services, such as water supply, flood control, recreation, and wildlife habitat. However, these rivers are increasingly threatened by pollution from agricultural runoff, industrial effluents, and untreated sewage. Urbanization exacerbates these issues, leading to water quality deterioration, habitat loss, and disruption of natural flow regimes. Understanding and quantifying the ecosystem service potential of urban rivers is vital for their protection and sustainable management. Engaging stakeholders from various sectors in river management planning is essential for developing effective solutions and ensuring the sustainable use of natural resources (Wang et al., 2014; Walsh et al., 2005).

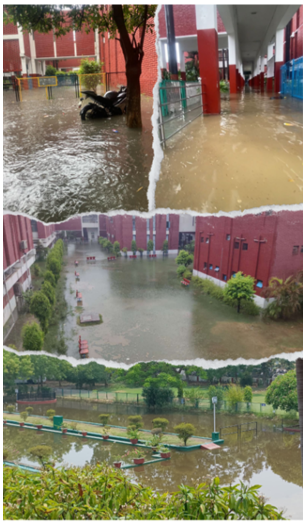
In India, while significant emphasis is placed on harnessing water resources in small towns, adequate drainage is often neglected. This neglect leads to waterlogging, threatening agriculture and public health by fostering waterborne diseases such as typhoid, hepatitis A, and dysentery. Despite mass movements by residents prompting action from authorities in many regions, in Aligarh, the response is often limited to blaming local government for insufficient facilities. Although the government bears ultimate responsibility, there is a persistent apathy towards essential services like sanitation and clean water, with allocated funds frequently misappropriated by officials (Chakraborty et al., 2019; Jain, 2016).

This study was planned as a part of ……….. project with the following objectives:
1- To perform analysis of the hospital wastewater microbiome, delineating the microbial diversity, sensitivity, antibiotic resistance and Carbapenem resistance genes.
2-To investigate the ecological consequences, focusing on water's physical, and chemical quality alterations, BOD and fecal contamination.
3-To evaluate the potential risks to public health as a resultant via risk assessment model using disease prevalence data
4- To propose evidence-based mitigation strategies for reducing hospital wastewater microbiome discharge's ecological and public health implications into river ecosystems

Material and Methods

Study Area

The study was conducted in the city of Aligarh, located at coordinates 27.900383, 78.072281 in the western part of the state of Uttar Pradesh, northern India. Aligarh is situated approximately 140 kilometers southeast of New Delhi, the capital of India. The Aligarh district forms part of the Central Ganga Plain of Uttar Pradesh, covering an area of 3,700.4 square kilometers. The district is bounded by the Ganga River to the west and the Yamuna River to the east. The entire district lies within the Upper Ganga Doab, characterized by its flat topography.

Water Sample Collection

A. Sewage Samples

Sewage samples were collected from three main hospitals in Aligarh: Jawaharlal Nehru Medical College, Deen Dayal Hospital, and Malkhan Singh Hospital. Additionally, samples were taken from the Dhorra Naala drainage line. The sewage water samples were specifically gathered from the outlet points of these hospitals.

B. Drinking Water Samples

Drinking water samples were collected for analysis. For physical and chemical properties, as well as coliform tests, sterilized bottles of 500ml capacity were used. Sterilized culture bottles were employed for culture and sensitivity testing.

Physical Properties Analysis

The physical properties analyzed included color, odor, temperature, total dissolved solids (TDS), pH, and dissolved oxygen (D.O.).

- **Color and Odor:** These properties were observed visually and noted accordingly.
- **Temperature, TDS, pH, and D.O.:** These parameters were measured using an automatic probe machine to ensure accuracy and consistency.

Chemical Properties Analysis

The chemical properties analyzed were Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD).

Microbiome: Culture of specimens collected from different sources was done on 5% sheep blood agar and Mac Conkey's agar. Antibiotic Resistance Assessment: On Cultures showing growth, antibiotic resistance profiling was done using Kirby Bauer disc diffusion test. Phenotypic detection was done for Multidrug resistance, presence of MRSA, VRSA and VRE in gram-positive bacteria and ESBL, ampC and CRE in gram-negative isolates.

Results:

Microbial Diversity and Antibiotic Resistance in Hospital Wastewater

The analysis of the hospital wastewater microbiome revealed a diverse range of bacterial colonies. E. coli dominated, comprising one-third of the total colonies, followed by Acinetobacter at 26%. Staphylococcus aureus accounted for 18% of the colonies, Pseudomonas 15%, Klebsiella 4%, and Citrobacter 2%. Additionally, a segment labeled "No growth" was noted, indicating the presence of non-viable bacteria or non-culturable forms. The resistance patterns among these bacteria showed that out of 39 tested colonies, 25 were sensitive to meropenem while 14 exhibited resistance. Further analysis of clinical samples indicated complete carbapenem resistance in all tested colonies of Pseudomonas and Acinetobacter, and three out of three Klebsiella colonies. In contrast, Citrobacter and E. coli showed no resistance to carbapenem. Notably, data for Staphylococcus aureus were unavailable, limiting the scope of resistance profiling for this bacterium.

Ecological Consequences and Water Quality Assessment

The physical and chemical quality of water samples collected from various sites was analyzed to investigate the ecological impact of hospital wastewater discharge. Most samples were clear, aligning with the ideal color standards, except for sample #19 (Chautaal), which exhibited a greenish color, indicating potential contamination. Unpleasant odors were noted in samples #2 and #19, suggesting the presence of odorous compounds or anaerobic bacterial activity. All samples fell within the recommended pH range of 6.5 to 8.5, crucial for maintaining aquatic life and chemical balance. Most samples had total dissolved solids (TDS) levels below the World Health Organization (WHO) limit of 1000 mg/L, indicating acceptable mineral and salt concentrations. The temperatures of all samples were within a reasonable range, supporting typical microbial and chemical processes in the water. However, some samples, particularly #20 and #27, had low dissolved oxygen (DO) levels, which can adversely affect aquatic organisms and indicate poor water quality. Biochemical oxygen demand (BOD) values ranged from 6.7 mg/L to 7.14 mg/L, suggesting moderate pollution levels. Chemical oxygen demand (COD) values ranged from 108 mg/L to 306 mg/L, generally falling within expected ranges for sewage water, but with some samples nearing the upper limit for typical disposal standards.

Public Health Risks and Prevalence of Infectious Diseases

A comprehensive risk assessment was conducted using disease prevalence data, focusing on Hepatitis A and E and the Widal test results. Between January and June, 1128 samples were tested for Hepatitis A and E, with 143 positive cases: 74 for Hepatitis A, 46 for Hepatitis E, and 23 co-infections. This data highlights a significant public health concern, with a notable increase in positive cases observed in June, potentially correlating with increased microbial loads in warmer months. Additionally, the Widal test conducted over six months revealed 40 positive samples out of 901 tested, indicating the presence of Salmonella infections. Antibiotic sensitivity profiles showed high sensitivity to Levofloxacin, Ceftriaxone, Meropenem, Imipenem, Ceftazidine, and Chloramphenicol, with over 80% of samples responding well to these antibiotics. However, approximately 20% of samples showed resistance to Gentamicin and Aztreonam, and around 15% were resistant to Doxycycline. These findings underscore the public health risks associated with antibiotic-resistant bacteria in hospital wastewater, necessitating further analysis and mitigation strategies. The presence of antibiotic-resistant bacteria in the water supply poses a significant threat, potentially leading to outbreaks of hard-to-treat infections. Effective mitigation strategies are crucial to protect urban river ecosystems and public health, including advanced wastewater treatment processes and stringent monitoring of hospital effluents.

References for water quality

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These references provide the standard values for water quality parameters.

Discussion:

Our study assessed the ecological and public health implications of hospital wastewater microbiome discharge into urban river ecosystems, focusing on microbial diversity, antibiotic resistance, and water quality parameters.

Microbial Diversity and Antibiotic Resistance

The dominance of E. coli and Acinetobacter in our hospital wastewater samples aligns with other studies. For instance, research by Urban et al. (2023) found that E. coli was the most prevalent bacteria in hospital wastewater, followed closely by Acinetobacter and Staphylococcus aureus. Similarly, our findings on carbapenem resistance among Acinetobacter and Pseudomonas species were corroborated by Guerra et al. (2014), who reported high levels of antibiotic-resistant bacteria in hospital effluents. Further, our study highlighted the prevalence of multiple antibiotic resistance genes in these bacteria, consistent with findings from studies like those of Manaia (2017) and Rodriguez-Mozaz et al. (2015), who emphasized the role of hospital effluents in spreading antibiotic resistance genes in the environment.

However, our observation of no carbapenem resistance in E. coli contrasts with findings from Hecht (2004), who documented significant carbapenem resistance in E. coli isolates from hospital wastewater. This discrepancy could be attributed to regional variations in antibiotic usage and infection control practices. Moreover, our study did not find data for Staphylococcus aureus, a gap also noted by Hu et al. (2018), emphasizing the need for comprehensive monitoring of all significant pathogens. Additionally, the presence of non-culturable bacteria indicated by the “No growth” segment in our study echoes the findings of Janda and Abbott (2007), who discussed the limitations of traditional culturing techniques in detecting all microbial diversity.

Water Quality Parameters

Our study showed that most water samples met WHO guidelines for pH and TDS but had issues with odor, color, and dissolved oxygen (DO) levels. These findings are consistent with those of Habit et al. (2006), who observed similar water quality issues in rivers receiving urban wastewater. The greenish color observed in one of our samples exceeds the recommended limit and could be indicative of algal growth, as discussed by Harada et al. (2008), who linked such discoloration to nutrient-rich effluents promoting algal blooms. The presence of algal growth is further supported by studies like those of Carey et al. (2012), which found nutrient-rich effluents contributing to harmful algal blooms.

Furthermore, low DO levels in some samples, as noted in our study, were also reported by Hamdhani et al. (2020), who highlighted the detrimental effects of effluent discharges on aquatic life due to oxygen depletion. The BOD and COD levels in our samples, although within expected ranges, point to moderate pollution, similar to findings by Holten-Lützhøft et al. (2000), who documented comparable BOD and COD values in wastewater-impacted rivers. These parameters are crucial indicators of organic pollution, as highlighted by Metcalf & Eddy (2014), which detailed how high BOD and COD values can lead to severe oxygen depletion and harm aquatic organisms.

Public Health Risks

The prevalence of Hepatitis A and E, along with co-infections, in our samples underscores the public health risks associated with wastewater discharge. This is in line with the study by Caldwell et al. (2010), who found a significant correlation between wastewater contamination and increased incidence of waterborne diseases. Additionally, our Widal test results, indicating a 4.4% positivity rate over six months, are consistent with those reported by Carlsson et al. (2000), who found similar rates of enteric fever in regions affected by wastewater pollution. The risk assessment model used in our study aligns with the frameworks proposed by WHO (2004) for evaluating public health risks from wastewater. Moreover, the detection of antibiotic-resistant bacteria poses a severe threat to public health, as documented by Davison et al. (2000), who emphasized the role of environmental reservoirs in the spread of resistance genes. Studies by Rizzo et al. (2013) and Michael et al. (2014) also highlight the significant risk posed by antibiotic-resistant bacteria and genes present in hospital effluents, which can transfer to pathogenic bacteria and exacerbate the problem of antibiotic resistance in clinical settings.

Comparison with Global Studies

Globally, the implications of hospital wastewater on urban rivers have been extensively studied. Kim et al. (2007) and Carmichael et al. (1993) both reported significant environmental and public health risks associated with untreated or inadequately treated hospital effluents. Their findings of high antibiotic resistance and microbial diversity in effluent-receiving waters are consistent with our study. The global perspective is further supported by studies such as that by Kümmerer (2009), which discussed the environmental impact of pharmaceuticals and their metabolites in hospital wastewater on a worldwide scale.

In contrast, some studies, like that by Chezhien et al. (2013), found lower levels of microbial contaminants and antibiotic resistance in regions with advanced wastewater treatment technologies, highlighting the critical role of effective treatment processes. Our study emphasizes the need for upgrading wastewater treatment facilities to mitigate the risks identified. The effectiveness of advanced treatment methods, such as membrane bioreactors and advanced oxidation processes, has been documented by Luo et al. (2014), which found significant reductions in antibiotic-resistant bacteria and genes following advanced treatment.

Furthermore, studies by Pruden et al. (2006) and Baquero et al. (2008) provide insights into the mechanisms of resistance gene transfer in the environment and underscore the importance of controlling antibiotic residues in wastewater. These studies highlight the complexity of managing antibiotic resistance in the environment and the need for a multifaceted approach that includes improving wastewater treatment, reducing antibiotic use, and implementing stringent regulations.

Conclusion and Recommendations:

Our study contributes to the growing body of evidence that hospital wastewater discharges pose significant ecological and public health risks. The high prevalence of antibiotic-resistant bacteria and pathogens, coupled with alterations in water quality parameters, underscores the need for stringent monitoring and improved wastewater treatment practices. Future research should focus on developing and implementing advanced treatment technologies to effectively reduce microbial and chemical pollutants in hospital effluents. The integration of real-time monitoring systems and the application of new biotechnologies, such as bioaugmentation and constructed wetlands, as suggested by Vymazal (2010), could provide sustainable solutions to mitigate these risks.

In summary, the comparison of our findings with those from other studies demonstrates both the ubiquity of the problem and the variability in its extent and impact. This variability highlights the need for localized studies and tailored mitigation strategies to address the specific challenges of each region. By adopting a comprehensive and evidence-based approach, we can better protect both public health and the environment from the adverse effects of hospital wastewater discharges. Collaboration between public health authorities, environmental agencies, and wastewater treatment facilities is crucial to developing and implementing effective policies and practices.

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