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Original Article

Impact of fumigation on Microbial Contamination in Pediatric Intensive Care Unit Equipment: A Comparative Culture-Based Study at Bangladesh Shishu Hospital & Institute

Nigha Zannat Dola[1], Md. Mahbubul Hoque[2], Mohammed Akter Hossan Masud[3], Rumana Parveen[4]

[1]Assistant Professor, Department of Microbiology, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh; [2]Professor, Department of Critical Care Paediatrics (PICU & NICU), Bangladesh Shishu Hospital & Institute, Dhaka, Bangladesh; [3]Assistant Professor, Paediatric Intensive Care Unit, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh; [4]Assistant Professor, Paediatric Intensive Care Unit, Bangladesh Shishu Hospital & Institute, Dhaka, Bangladesh

Abstract

Background: Environmental contamination in critical care settings poses significant risk for healthcare-associated infections (HAIs). ***Objective:*** This study was conducted to observe the effectiveness of fumigation in the Pediatric Intensive Care Unit (PICU) of Bangladesh Shishu Hospital and Institute (BSHI), Dhaka, Bangladesh. ***Methodology:*** This pre–post observational study was conducted in the Pediatric Intensive Care Unit (PICU) of Bangladesh Shishu Hospital and Institute (BSHI), Dhaka, Bangladesh, from January to June 2025. Swab samples were collected from 8 high-touch items within the PICU before fumigation (19/06/2025) and from 12 items after fumigation (22/06/2025). All samples were incubated at 37°C overnight, and culture results were reported by BSHI Microbiology Department. The culture media supported the growth of a wide range of bacterial and fungal species. Outcomes were classified based on presence or absence of microbial growth and species identification. Reduction in positive cultures and pathogenic diversity were used to evaluate fumigation efficacy. ***Results:*** Pre-Fumigation Findings, Out of 8 items tested: 87.5% (7/8) showed positive microbial growth. Notable organisms: Staphylococcus sp., Pseudomonas sp., Klebsiella pneumoniae, Acinetobacter sp., Bacillus sp., fungi. Multiple organisms were isolated from beds, incubators, and ambu bags.Post-Fumigation Findings, Out of 12 items tested: 50% (6/12) showed no growth.Remaining positive cultures revealed Bacillus sp., Staphylococcus sp., Streptococcus sp.High-touch items like beds and incubators still harbored pathogens, albeit fewer in number. ***Conclusion:*** Fumigation in the PICU of Bangladesh Shishu Hospital and Institute significantly reduced environmental microbial contamination, decreasing the proportion of positive cultures and eliminating several clinically important pathogens, although persistent growth on some high-touch surfaces indicates the need for ongoing infection prevention and environmental cleaning measures.

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Correspondence: Dr. Nigha Zannat Dola, Assistant Professor, Department of Microbiology, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh; Email: nzdola@yahoo.com; **ORCID:** https://orcid.org/0009-0000-5477-2063; Contact no: +880 1737-991774

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Introduction

Infections acquired during hospital stays, known as healthcare-associated infections (HAIs), represent a formidable challenge to patient safety and public health worldwide[1]. These infections are particularly dangerous in intensive care settings, where patients are often immunocompromised and highly vulnerable[2,3].Pediatric intensive care units (PICUs) house critically ill children whose underdeveloped immune systems are less capable of

resisting opportunistic pathogens[4].

Surfaces and equipment within hospital environments can act as reservoirs for a variety of pathogenic microorganisms. These pathogens, if not adequately managed, contribute significantly to nosocomial infection rates[5-6]. Commonly implicated organisms include *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Klebsiella pneumoniae*, many of which exhibit multidrug resistance[7-8].

Environmental contamination in healthcare settings arises primarily from direct contact with infected patients, healthcare personnel, and aerosol dispersion. In PICUs, high-touch surfaces such as beds, ventilators, nasal cannulae, monitors, and humidifiers are continuously exposed to biological materials, thereby accumulating microbial load[9]. These contaminated surfaces can serve as vectors for horizontal transmission of pathogens between patients and staff[10-11]. To reduce such environmental contamination, healthcare facilities deploy routine and terminal cleaning protocols, including chemical disinfection, fumigation, and mechanical decontamination measures[12]. Among these, fumigation with agents like formaldehyde, hydrogen peroxide vapor, and peracetic acid is a traditional and widely practiced method for whole-room decontamination[13,14]. Fumigation disperses biocidal chemicals in the form of gas, which penetrates accessible surfaces and air spaces, thereby reducing microbial bioburden.

Although fumigation has been reported to significantly reduce Gram-negative bacteria, its efficacy against Gram-positive cocci and spore-forming bacteria remains variable[15,16]. Gram-positive bacteria, such as Staphylococcus species, have thicker peptidoglycan cell walls that enhance resistance to chemical agents.[17] Similarly, spore-forming organisms like *Bacillus* species are capable of producing dormant structures that can endure harsh chemical and thermal treatments[18-19]. These inherent characteristics make such microbes particularly difficult to eradicate using conventional fumigation.

Several studies have documented residual microbial presence even after rigorous fumigation protocols[9,20]. In particular, high-touch areas and medical devices often show post-fumigation survival of resilient organisms, posing a persistent risk for HAIs[21]. The limitations of fumigation have prompted investigations into alternative or supplementary methods, such as aerosolized fogging systems and ultraviolet (UV) disinfection technologies[22,14].

Fogging involves the dispersion of fine droplets of disinfectants using high-pressure nozzles or thermal means, enabling even surface coverage, including hard-to-reach or shadowed zones[15]. Recent evidence suggests that fogging may surpass fumigation in effectiveness by maintaining surface moisture longer and offering prolonged microbial exposure to the disinfectant[23,24].

Given the evolving landscape of disinfection strategies, it becomes imperative to assess the real-world efficacy of fumigation within hospital settings, especially in sensitive units such as the PICU. This study was conducted to evaluate the microbial contamination levels of various pieces of PICU equipment at Bangladesh Shishu Hospital & Institute before and after fumigation. It aims to determine the types of organisms that persist post-fumigation and explore whether fogging could offer a more comprehensive solution for environmental decontamination.

Methodology

Study Design and Setting: This cross-sectional study was conducted in a tertiary care microbiology laboratory to isolate bacterial pathogens from environmental and equipment surfaces using STGG (Skim milk–Tryptone–Glucose–Glycerol) transport medium. All sample collection and processing were carried out under strict aseptic conditions to prevent contamination[25].

Sample Collection: The materials included sterile Dacron or rayon swabs, STGG medium pre-aliquoted in sterile cryovials (1 mL), 70% ethanol, sterile gloves, sterile saline (optional), transport forms, and a cool box with ice packs for transport[25].

Sampling Sites: Samples were collected from environmental surfaces & equipment such as high Flow nasal cannula prong, high flow nasal cannula humidifier, incubator, ventilator humidifier, bed, ambu bag, cardiac monitor, floor before & after fumigation. After fumigation additional samples were also collected from oxygen flow meter, incubator (another room), intubation tray (Laryngeoscope blade), bed side locker. All surfaces were pre-identified and swabbed during routine working hours to mimic normal contamination risk[26].

Sampling Technique: Sterile gloves were worn, and swab tubes were disinfected externally before use. A sterile swab was moistened with sterile saline if needed and used to swab a 10×10 cm surface area or full equipment surface using firm, rotating strokes. The swab was then inserted into a sterile tube containing 1 mL of STGG medium, the shaft was broken aseptically, and the tube was sealed, labeled, and placed into a cold transport box.[25]

If immediate processing was not possible, samples were stored at –70°C to preserve bacterial viability[25-28].

Sample Processing

Inoculation onto Culture Media: Upon arrival at the lab, the STGG tubes were vortexed for 10–15 seconds to suspend the collected material[29]. A 10 µL sterile calibrated loop was used to inoculate the sample onto Blood Agar (BA) and MacConkey Agar (MAC) using quadrant streaking technique[30]. Blood Agar supports the growth of a wide range of organisms, especially fastidious ones, and allows for observation of hemolysis, while MacConkey Agar selectively supports Gram-negative bacilli and differentiates them based on lactose fermentation[30].

Incubation: Blood Agar plates were incubated at 35 to 37°C in 5% CO_2 for 18 to 24 hours, and MacConkey Agar plates were incubated aerobically at 35 to 37°C for 18 to 24 hours[3]. After incubation, plates were examined for colony morphology, pigmentation, hemolysis (on BA), and lactose fermentation on MacConkey Agar[27].

Identification of Bacterial Isolates: All morphologically distinct colonies were subjected to Gram staining to determine Gram reaction, shape, and cellular arrangement[27]. Depending on Gram stain results and colony morphology, conventional biochemical tests were performed for bacterial identification. These included the catalase and coagulase tests for Gram-positive cocci, and a series of tests for Gram-negative bacilli including Triple Sugar Iron (TSI), Indole, Citrate, Urease, Motility, and Oxidase tests[28].

Quality Control: Control strains such as Escherichia coli ATCC 25922 and Staphylococcus aureus ATCC 25923 were used to verify the accuracy of culture media and biochemical tests.[28]

Data Collection: All results including colony morphology, Gram stain characteristics, and biochemical reactions were recorded in structured forms and then entered into electronic laboratory data sheets for further analysis and storage[29].

Statistical Analysis: All statistical analysis were done by using SPSS (Statistical Package for Social Science) version 21 windows package.

Ethical issues: The study protocol was approved by the institutional review committee. Due permission will be taken from proper authority. All concerned were informed about the study.

Results

Before fumigation, a total of 8 samples were collected in different places of PICU. Among them 7 samples showed positive culture (Table 1).

Table 1: Isolated Organism from Different Places and Equipment of PICU before Fumigation

Sample Name	Culture Result	Isolated Organism(s)
High Flow Nasal Cannula Prong	Positive	*Staphylococcus* sp.
High Flow Nasal Cannula Humidifier	Positive	*Pseudomonas* spp *Klebsiella pneumonia*
Incubator	Positive	*Staphylococcus* spp, Fungal growth
Ventilator Humidifier	Positive	*Bacillus* spp
Bed	Positive	*Pseudomonas* spp, *Acinetobacter* spp, *Bacillus* sp.
Ambu Bag	Positive	*Pseudomonas* spp, *Bacillus* sp.
Cardiac Monitor	Negative	Not applicable
Floor	Positive	*Staphylococcus* spp,*Enterobacter* sp., *Pseudomonas* sp.

After fumigation, a total 8 samples were collected in the same places of PICU. Additional 4 samples were also collected to see the efficacy of fumigation. Among them, 7 samples showed positive culture (Table 2).

Table 2: Isolated organisms from different places & equipment of PICU after fumigation

Sample Name	Culture Result	Isolated Organism(s)
High Flow Nasal Cannula Prong	Negative	No Growth
High Flow Nasal Cannula Humidifier	Positive	*Bacillus* sp.
Incubator	Positive	*Bacillus* sp.
Ventilator Humidifier	Positive	*Streptococcus* sp.,*Bacillus* sp.
Bed	Positive	*Streptococcus* sp.,
Ambu Bag	Negative	No Growth
Cardiac Monitor	Negative	No Growth
Floor	Positive	*Streptococcus* sp., *Streptococcus* sp.
Oxygen flow meter	Negative	No Growth
Incubator (2nd Room)	Negative	No Growth
Intubation Tray (Laryngoscope Blade)	Negative	No Growth
Bedside Locker	Positive	*Streptococcus* spp, *Bacillus* spp

Table 3: Culture Positivity and Negativity Rate of Before and After Fumigation

Description	Before Fumigation	After Fumigation
Total Samples Taken	8	12
Positive Cultures	7	6
Negative Cultures	1	6
Positivity Rate	87.5%	50.0%
Negative Rate	12.5%	50.0%

Discussion

This study assessed microbial contamination in the PICU before and after fumigation. Before fumigation, 87.5% of the samples showed microbial growth. The most commonly identified organisms included *Pseudomonas* species, *Staphylococcus* species, *Bacillus* species and *Acinetobacter* species. These organisms are significant contributors to healthcare-associated infections (HAIs), particularly in ICUs[5].

After fumigation, the positivity rate dropped to 50.0%, indicating partial decontamination success. Similar findings were reported by Weber et al[9] where environmental decontamination significantly reduced pathogen transmission in critical care. Key equipment like the high-flow nasal cannula prong and ambu bag showed no growth post-fumigation. These results highlight the effectiveness of fumigation on certain high-touch, less complex surfaces. However, persistent contamination on beds, incubators, and ventilator humidifiers was observed.

Bacillus species, a spore-forming bacterium, remained after fumigation, reflecting its resistance to routine disinfectant[10]. *Streptococcus* species emerged in several sites after fumigation, not observed before. This could be due to post-fumigation recolonization or procedural contamination. Studies have shown poor air circulation or incomplete fumigant dispersion can lead to such outcomes[30]. Dancer[31] highlighted that environmental cleaning reduces MRSA and other pathogens but is rarely sufficient alone.

Manual cleaning before and after fumigation is crucial to remove biofilm and organic matter[32]. Surface porosity, design complexity, and humidity contribute to microbial persistence[23]. The floor remained contaminated, likely due to constant re-exposure from foot traffic and airborne deposition. Boyce et al[11] emphasized that frequent manual cleaning of floors and mobile equipment. The study's results echo findings by Carling et al[21], who found that combined cleaning-monitoring strategies improve outcomes[33].

Four additional sites were sampled post-fumigation; 3 out of 4 remained sterile. This affirms fumigation's efficacy in initially uncontaminated or less-handled areas. Despite improvement, 6 of 12 samples remained positive after fumigation. This underlines that fumigation alone is not wholly reliable for microbial eradication. Therefore, an integrated cleaning protocol is essential. Use of sporicidal fogging agents, such as hydrogen peroxide vapor, is recommended[15]. Hydrogen peroxide fogging has been shown to eliminate Clostridium difficile spores effectively[14].

Adequate contact time and fog dispersion need to be ensured for maximal reach. In this context, fans or airflow modeling can aid in improving fumigant spread[34]. All ventilation points should be temporarily sealed during fumigation. Staff should undergo training on aseptic handling and post-cleaning procedures. Similar studies by Otter et al[9] stress the importance of surface disinfection combined with behavioral strategies[35].

Microbial surveillance post-cleaning is necessary to evaluate protocol efficacy. Swab testing monthly or biweekly can detect recontamination early. Manual scrubbing is especially vital on textured or grooved surfaces. UV-C disinfection may complement fumigation in inaccessible corners[23]. Consider zone-wise fogging rotation to limit operational disruption.

Equipment that cannot tolerate fogging should be disinfected separately using wipes or autoclaving if possible. The persistence of *Bacillus* species calls for regular use of spore-killing agents. Disinfection efficacy should be audited by third-party microbiological sampling. Hospital infection control teams should adapt cleaning frequencies based on microbial burden. Data-driven adjustments can optimize resource allocation. The findings here are consistent with recommendations from the CDC and WHO for ICU decontamination practices[36].

Conclusion

This study reinforces the value of continuous improvement in environmental hygiene protocols. Fumigation is beneficial but not absolute it must be integrated with comprehensive IPC measures. Future studies may test the combined effect of fogging with air filtration upgrades.

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References

1.World Health Organization. Report on the burden of endemic health care-associated infection worldwide. Geneva: WHO; 2011.
2.Vincent JL. Nosocomial infections in adult intensive-care units. Lancet. 2003;361(9374):2068–77.
3.Kollef MH, Fraser VJ. Antibiotic resistance in the intensive care unit. Ann Intern Med. 2001;134(4):298–314.
4.Raymond J, Aujard Y. Nosocomial infections in pediatric patients: a European, multicenter prospective study. Infect Control Hosp Epidemiol. 2000;21(4):260–3.

5.Weber DJ, Rutala WA, Miller MB, Huslage K, Sickbert-Bennett E. Role of hospital surfaces in the transmission of emerging health care-associated pathogens: norovirus, Clostridium difficile, and Acinetobacter species. Am J Infect Control. 2010;38(5 Suppl 1):S25–33.
6.Dancer SJ. Importance of the environment in methicillin-resistant Staphylococcus aureus acquisition: the case for hospital cleaning. Lancet Infect Dis. 2008;8(2):101–13.
7.Sievert DM, Ricks P, Edwards JR, Schneider A, Patel J, Srinivasan A, et al. Antimicrobial-resistant pathogens associated with healthcare-associated infections. Infect Control Hosp Epidemiol. 2013;34(1):1–14.
8.Magill SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, et al. Multistate point-prevalence survey of health care–associated infections. N Engl J Med. 2014;370(13):1198–208.
9.Otter JA, Yezli S, French GL. The role played by contaminated surfaces in the transmission of nosocomial pathogens. Infect Control Hosp Epidemiol. 2011;32(7):687–99.
10.Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? BMC Infect Dis. 2006;6:130.
11.Boyce JM. Environmental contamination makes an important contribution to hospital infection. J Hosp Infect. 2007;65 Suppl 2:50–4.
12.Rutala WA, Weber DJ. Disinfection and sterilization in health care facilities: an overview and current issues. Infect Dis Clin North Am. 2016;30(3):609–37.
13.Sagripanti JL, Lytle CD. Sensitivity to ultraviolet radiation of Lassa, vaccinia, and Ebola viruses dried on surfaces. Arch Virol. 2011;156(3):489–94.
14.Otter JA, Yezli S, Perl TM, Barbut F, French GL. The role of 'no-touch' automated room disinfection systems in infection prevention and control. J Hosp Infect. 2013;83(1):1–13.
15.Hall L, Otter JA, Chewins J, Wengenack NL. Use of hydrogen peroxide vapor for deactivation of Mycobacterium tuberculosis in a biological safety cabinet and a room. J Clin Microbiol. 2007;45(3):810–5.
16.Fu TY, Gent P, Kumar V. Efficacy, efficiency and safety aspects of hydrogen peroxide vapor and aerosolized hydrogen peroxide room disinfection systems. J Hosp Infect. 2012;80(3):199–205.
17.Beveridge TJ. Structures of gram-negative cell walls and their derived membrane vesicles. J Bacteriol. 1999;181(16):4725–33.
18.Setlow P. Spores of Bacillus subtilis: their resistance to and killing by radiation, heat and chemicals. J Appl Microbiol. 2006;101(3):514–25.
19.Leggett MJ, McDonnell G, Denyer SP, Setlow P, Maillard JY. Bacterial spore structures and their protective role in biocide resistance. J Appl Microbiol. 2012;113(3):485–98.
20.Weber DJ, Anderson D, Rutala WA. The role of the surface environment in healthcare-associated infections. Curr Opin Infect Dis. 2013;26(4):338–44.
21.Carling PC, Parry MF, Von Beheren SM. Identifying opportunities to enhance environmental cleaning in 23 acute care hospitals. Infect Control Hosp Epidemiol. 2008;29(1):1–7.
22.Nerandzic MM, Cadnum JL, Pultz MJ, Donskey CJ. Evaluation of an automated ultraviolet radiation device for decontamination of Clostridium difficile and other healthcare-associated pathogens in hospital rooms. BMC Infect Dis. 2010;10:197.
23.Krishnan J, Fey G, Stansfield C, Landry L, Nguy H, Klassen S, et al. Evaluation of a dry fogging system for laboratory decontamination. Appl Biosaf. 2012;17(3):132–41.
24.Lemmen SW, Lewalter K, Prestel C, von Eiff C, Gastmeier P. Improved terminal disinfection of rooms contaminated with multidrug-resistant pathogens using an aerosol disinfection system. J Hosp Infect. 2014;86(1):22–6.
25.O'Brien KL, Bronsdon MA, Dagan R, Yagupsky P, Janco J, Elliott J, et al. Evaluation of a medium (STGG) for transport and storage of Streptococcus pneumoniae from nasopharyngeal secretions. J Clin Microbiol. 2001;39(3):1021–4.
26.Cheesbrough M. District Laboratory Practice in Tropical Countries, Part 2. 2nd ed. Cambridge: Cambridge University Press; 2006. p. 37–45.
27.Forbes BA, Sahm DF, Weissfeld AS. Bailey & Scott's Diagnostic Microbiology. 12th ed. St. Louis: Mosby Elsevier; 2007. p. 170–225.
28.Collee JG, Miles RS, Watt B. Tests for identification of bacteria. In: Collee JG, Fraser AG, Marmion BP, Simmons A, editors. Mackie & McCartney Practical Medical Microbiology. 14th ed. Edinburgh: Churchill Livingstone; 1996. p. 131–49.
29.Tille P. Bailey & Scott's Diagnostic Microbiology. 14th ed. St. Louis: Elsevier; 2017. p. 217–332.
30.Rutala WA, Weber DJ. Disinfection, sterilization, and control of hospital waste. In: Bennett JE, Dolin R, Blaser MJ, editors. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases. 8th ed. Philadelphia: Elsevier Saunders; 2015.
31.Dancer SJ. The role of environmental cleaning in the control of hospital-acquired infection. J Hosp Infect. 2009;73(4):378–85.
32.Griffith CJ, Cooper RA, Gilmore J, Davies C, Lewis M. An evaluation of hospital cleaning regimes and standards. J Hosp Infect. 2000;45(1):19–28.
33.Carling PC, Von Beheren S, Kim P, Woods C. Intensive care unit environmental cleaning: an evaluation in sixteen hospitals using a novel assessment tool. J Hosp Infect. 2008;68(1):39–44.
34.Weber DJ, Anderson DJ, Sexton DJ, Rutala WA. Role of the environment in the transmission of Clostridium difficile in health care facilities. Am J Infect Control. 2013;41(5 Suppl):S105–10.
35.Boyce JM, Havill NL, Otter JA, McDonald LC, Adams NM, Cooper T, et al. Impact of hydrogen peroxide vapor room decontamination on Clostridium difficile environmental contamination and transmission in a healthcare setting. Infect Control Hosp Epidemiol. 2008;29(8):723–9.
36.Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities. Atlanta, GA: CDC; 2003