Water Surveillance and Surgical Site Infection: A Prospective Study from a Tertiary Care Oncology Centre

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Abstract

Quality of water supplyin heath-care organisation (HCO) is often not taken seriously in many low to middle income countries (LMIC). Waterborne pathogens may come in contact with patients in various ways in HCOs which includes showering, bathing, drinking or in contact withimproperly cleaned medical devices. Hand colonization is another important source of transmission of health-care associated infections (HAIs), specially the Surgical site infections (SSI). Contaminated water system maycontribute to HAIs by various pathogens like coliforms and other opportunistic pathogens like *Pseudomonas aeruginosa, Burkholderia cepacia, Acinetobacter spp.* etc. Stringent implementation of water surveillance (WS) program along with immediate corrective action against the root cause of contamination should be mandatory in each HCO.

Keywords: heathcare organisation (HCO), healthcare associated infections (HAIs), Surgical site infections (SSI), water surveillance (WS), coliforms, *Pseudomonas spp.*

INTRODUCTION

Health care-associated infections (HAI) are the most frequent adverse event in any health-care organization (HCO). The endemic burden of these infectionsare significantly higher in low-and middle-income countries (LMIC) as compared to high-income countries (HIC). In high-income countries, approximately 30% of patients in intensive care units (ICU) are affected by at least one HAI which is 2-3 fold higher in LMIC.[1] In India, the overall prevalence of HAIs was found to be 7%, and surgical site infections (SSI) were the most common (33%).[2] Another study reveals 1.75 HAI cases per 1000 patient-days; SSIs being predominated HAI, 23.94%.[3]

Various studies suggest that environmental contamination is associated with HAIby multi-drug-resistant organisms (MDROs) [vancomycin-resistant enterococci (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), *Acinetobacter baumannii, Clostridium difficile,* and *Pseudomonas aeruginosa*], viruses, mycobacteria, and fungi.[4,5,6]

Contaminated water have been linked to numerous HAI outbreaks which isassociated with improper

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hand washing and inadequate cleaning of medical devices for reprocessing.[7] Study on availability of proper environmental conditions and standard precaution items over 78 LMIC including 129,557 HCO showed 50% lacked piped water.[8] Water supply in HCO are frequently overlooked although it is an essential manageable source to control HAI.[7]

Our study is to evaluate correlation between water condition of the operation theatre (OT) with SSIs that were traced over 2 years in a tertiary care hospital in Delhi along with the actions taken activities.

MATERIAL AND METHODS

This study was carried out in a 200 bedded tertiary care oncology centre over a period of 2 years, from December 2019 to December 2021. Water and SSI surveillance record per month were evaluated.

Water Surveillance (WS) Protocol of Hospital

HCO has formulated a protocol for WS. As per National Accreditation Board for Hospitals and Health Care Providers (NABH) 4th Edition, periodic surveillanceactivities were appropriately performed for Operation Theatre, which belongs to a high-risk areas (HRA).[9] One of the surveillance activities include monthly water culture and quarterly water quality testing.

WATER SAMPLE COLLECTION

Water samples were collected in heat sterilized bottles of 100 ml capacity. Water is allowed to run for 2-3 minutes prior to collection into the bottle.[10] Frequency of water collection for surveillance from OT is once in a month.

Microbiological evaluation: Multiple Tube Test (MTT)[10]

MTT was done using MacConkey broth Purple (MCBP) (double strength) with Bromocresol purple (BCP) (HiMedialabs).[11]

50 ml and 10 ml volumes of MCBP at double strength and 5 ml at single strength are placed into tubes and bottles containing inverted air free Durham tubes. Then aseptically add 50 ml volume and 10 ml volume of water into bottle/tubes containing corresponding 50 ml and 10 ml volumes of double strength MCBP and five 1 ml volumes into tubes containing 5 ml of single strength medium. [Fig 1] *Escherichia coli* American Type Culture Collection (ATCC) 25922 was used as positive control while *Staphylococcus aureus* ATCC 25923 was used as negative control.

Fig. 1: Multiple Tube Test using MacConkey broth Purple (MCBP) (double strength) with Bromocresol purple (BCP) with positive and negative controls

Bottles and tubes are incubated aerobically at 37 for 24 to 48 hours.

Lactose fermenting organisms (Coliforms) turns the media from blue to yellow. Non-lactose fermenting organisms (example, *Pseudomonas spp*.) donot change the colour but there will be turbidity and pellicle formation in the liquid medium. Positive tubes were further sub-cultured on Blood agar and MacConkey agar for identification, morphology, biochemical testing and antibiogram.

Most probable number (MPN)/ 100 ml of bacteria was derived from McCrady's table used which is based on the numbers of positive and negative reactions in replicate tests of different volumes of the sample examined by the multiple tube method.[10,12]

Water Quality were Categorized into 4 Groups:[12]

Excellent: 0 MPN/100 ml of water

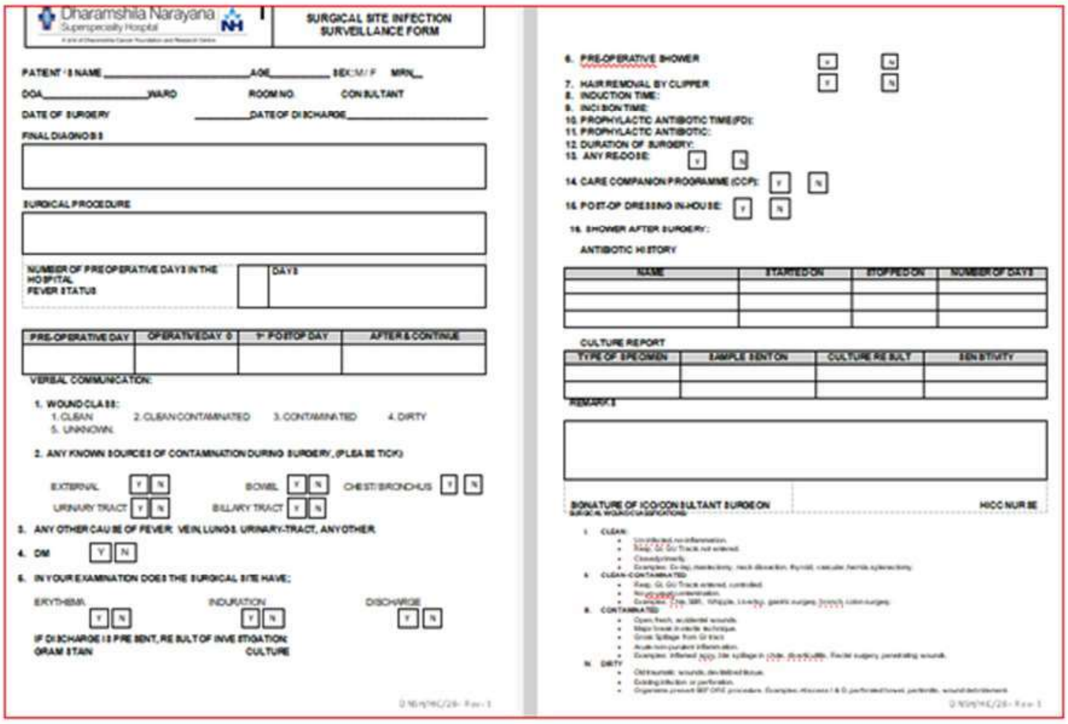
Satisfactory: 1-3 MPN/100 ml of water

Suspicious: 4-9 MPN/100 ml of water

Unsatisfactory: >=10 MPN/100 ml of water

Surveillance of SSI: [13,14]

SSI Data collection form is prepared keeping WHO peri-operative and post-operative data collection forms.[13] (Fig. 2)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SURGICAL SITE INFECTION SURVEILLANCE FORM

PATIENT'S NAME ____ AGE ____ SEX: M / F MRN ____

DOA ____ WARD ____ ROOM NO. ____ CONSULTANT ____

DATE OF SURGERY ____ DATE OF DISCHARGE ____

FINAL DIAGNOSIS

SURGICAL PROCEDURE

NUMBER OF PREOPERATIVE DAYS IN THE HOSPITAL | DAYS

FEVER STATUS

PRE-OPERATIVE DAY	OPERATIVE DAY 0	1st POSTOP DAY	AFTER & CONTINUE

VERBAL COMMUNICATION:

1. WOUND CLASS: 1. CLEAN 2. CLEAN CONTAMINATED 3. CONTAMINATED 4. DIRTY 5. UNKNOWN
2. ANY KNOWN SOURCES OF CONTAMINATION DURING SURGERY, (PLEASE TICK)
EXTERNAL Y N BOWEL Y N CHEST/BRONCHUS Y N
URINARY TRACT Y N BILLARY TRACT Y N
3. ANY OTHER CAUSE OF FEVER: VEIN, LUNGS, URINARY-TRACT, ANY OTHER
4. DM Y N
5. IN YOUR EXAMINATION DOES THE SURGICAL SITE HAVE:
ERYTHEMA Y N INDURATION Y N DISCHARGE Y N

IF DISCHARGE IS PRESENT, RESULT OF INVESTIGATION:
GRAM STAIN CULTURE

6. PRE-OPERATIVE SHOWER Y N
7. HAIR REMOVAL BY CLIPPER Y N
8. INDUCTION TIME:
9. INCISION TIME:
10. PROPHYLACTIC ANTIBIOTIC TIME(FD):
11. PROPHYLACTIC ANTIBIOTIC:
12. DURATION OF SURGERY:
13. ANY RE-DOSE: Y N
14. CARE COMPANION PROGRAMME (CCP): Y N
15. POST-OP DRESSING IN-HOUSE: Y N
16. SHOWER AFTER SURGERY:

ANTIBIOTIC HISTORY

NAME	STARTED ON	STOPPED ON	NUMBER OF DAYS

CULTURE REPORT

TYPE OF SPECIMEN	SAMPLE SENT ON	CULTURE RESULT	SENSITIVITY

REMARKS

SIGNATURE OF ICO/CONSULTANT SURGEON HICC NURSE

SURGICAL WOUND CLASSIFICATIONS:

I. CLEAN: Uninfected, no inflammation. Resp, GI, GU Tracts not entered. Closed primarily.
II. CLEAN-CONTAMINATED: Resp, GI, GU Tracts entered, controlled. No unusual contamination.
III. CONTAMINATED: Open, fresh, accidental wounds. Major break in sterile technique. Gross spillage from GI tract. Acute non-purulent inflammation.
IV. DIRTY: Old traumatic wounds, devitalized tissue. Existing infection or perforation.

Fig. 2: Surveillance form for Surgical site infection

Incidence of SSI=Number of SSI cases detected during the surveillance period x 100/Number of total surgical patients during the surveillance period

Follow up period for SSI was considered as 30 days (eg. Neck surgery, gastric surgery etc) and 90 days (eg. Cardiac surgery, Breast surgery etc.) as per CDC guideline. The wounds were categorized into four types: Clean (C), Clean-Contaminated (CC), Contaminated (CO), and Dirty/Infected (D).[14]

As per World Health Organization (WHO), the pooled SSI incidence was 5.6 per 100 surgical procedures (95% CI: 2.9–10.5).[15] In our HCO, average rate of SSI is 1.95 (95% Confidence Interval 1.74 to 2.63).

RESULTS:

Overall HAI in our HCO over 2 years (December 2019 to November 2021) were found to be 82; out of which SSI predominated with 57% (47/82) (Fig. 3)

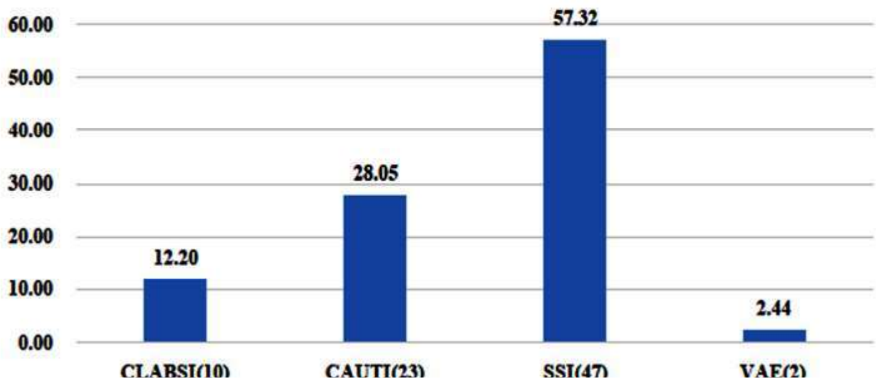

Fig. 3: Distribution of Hospital Acquired Infections (%) over 2 years

Note: CLABSI:Central line associated blood stream infection; CAUTI: Catheter associated urinary tract infection; SSI: Surgical site infection; VAE: Ventilator associated pneumonia

Out of all SSIs, 78.72% (37/47) were clean contaminated wound, 19.15% (9/47) were contaminated wound. (Fig 4a) Majority of the SSIs were related to oncology surgeries, 93.62%(44/47). [Fig 4b]

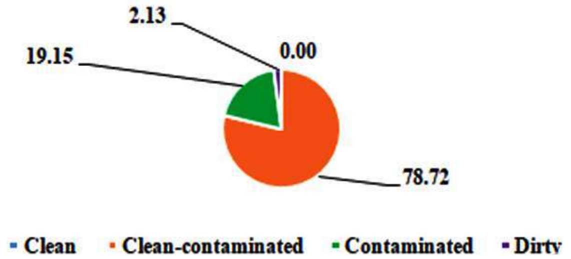

Fig. 4a: Percentage of distribution of Surgical Site Infections (n=47) as per classification

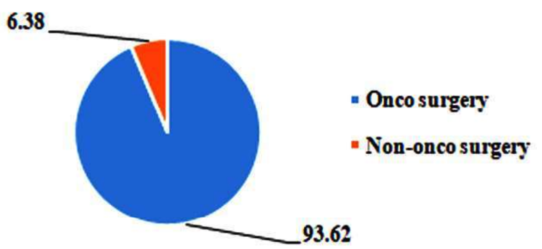

Fig. 4b: Percentage of distribution of Surgical Site Infections (n=47) as per Oncology or Non-oncology.

WS in OT showed excellent water quality with 0 MPN/100 ml in 62.50%, suspicious water quality with 4-10 MPN/100 ml in 4.17% and unsatisfactory water quality with >=10 MPN/100 ml in 33.33% over 2 years. (Fig. 5)

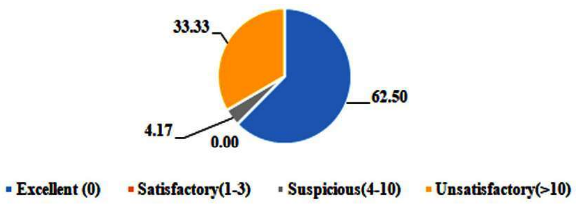

Fig. 5: Rate of distribution of water quality in Surveillance Water Culture as per MPN/100 ml

Fig. 6: Pall Aquasafe Water filters installation

Surveillance of SSI over 2 years (December 2019 to November 2021) showed highest rate of SSI in October 2020 (4.95%) followed by August 2020 (3.87%). (Table 1)

Recursive partitioning analysis was carried out using rpart package[16] in R[17] to generate optimal cut off for SSI which was found to be 1.95 over these 2 years (Dec-19 to Nov-21) which was considered as benchmark for SSI in our institute.

Considering 1.95 as benchmark for SSI, relation of growth in WS and number of SSI were established shown in Fig 5. There is statistically significant correlation between SSI rate >1.95 with water contamination with p value 0.0147. (Table 1)

Table 1: Distribution of Surgical Site Infections Over 2 years Along with Result of Water Surveillance (WS) in OT

Months	No. of SSI	Total No. of surgeries	SSI (%)	OT Water Surveillance culture (Growth=1; No growth=0)
Dec 19	3	165	1.82	0
Jan 20	2	154	1.30	0
Feb 20	1	99	1.01	0
March 20	1	51	1.96	0
April 20	0	146	0.00	0
May 20	1	105	0.95	0
June 20	2	137	1.46	1
July 20	2	132	1.52	0
August 20	6	155	3.87	1
Sept 20	2	144	1.39	1
Oct 20	5	101	4.95	1
Nov 20	2	143	1.40	0
Dec 20	1	158	0.63	0
Jan 21	0	169	0.00	0
Feb 21	0	166	0.00	0
March 21	0	110	0.00	1
April 21	2	101	1.98	1
May 21	1	157	0.64	0
June 21	4	199	2.01	1
July 21	5	203	2.46	1
August 21	1	210	0.48	0
Sept 21	1	231	0.43	1
Oct 21	4	207	1.93	0
Nov 21	1	207	0.48	0

Water culture growth and growth in SSI are correlated by phenotypic method and antibiogram. *Pseudomonas spp.* was the predominating isolate in water culture with considerable MPN/100 ml. Type of growth in WS and similar isolates retrieved from SSI were compared. Species with similar phenotype and antibiogram were considered having common source of infection. (Tab 2)

Tab1e 2: Correlation of Growth in water culture and Growth in SSI (Phenotyping and Antibiogram)

Months	Organism in water culture (>180 MPN/100 ml)	No. of SSI	Same organism in SSI (No.)
June 20	*Pseudomonas spp.*	2	*Pseudomonas spp.* (1)
August 20	*Pseudomonas spp.*	6	*Pseudomonas spp.* (1)
Sept 20	*Pseudomonas spp.*	2	nil
Oct 20	*E.coli* (faecal coliform)	5	*E.coli*(1)
March 21	*Pseudomonas spp.*	0	nil
April 21	*Pseudomonas spp.*	2	nil
June 21	*Pseudomonas spp.* and *Klebsiella pneumoniae*	4	*Pseudomonas spp.* (1) *Klebsiella pneumoniae* (2)
July 21	*Pseudomonas spp.*	5	*Pseudomonas spp.* (1)
Sept 21	*Pseudomonas spp.*	1	nil

ACTIONS TAKEN

- ***Inter-laboratory comparison:*** Inter-laboratory comparison of water testing is done from National Accreditation Board for Testing and Calibration Laboratories (NABL) accrediated laboratories which not only includes water culture but also checks various other parameters of water [pH, Total Dissolved Solids (TDS), General parameters like aluminium, ammonia, boron, calcium etc; Toxic parameters like cyanide, lead etc. and conductivity]. No discrepancy was observed in culture results.
- ***Local chlorination of the tanks:*** Chlorination is done on daily basis in the supply water of the hospital. Daily monitoring is done for TDS, Ph, Free chlorine (Ionexchange, Indion). Residual chlorine level is targetted to keep in between 0.2-05 mg/L.[18]
- ***Cleaning of the tanks:*** For mechanized de-watering, a portable submersible was used which used to empty the tank with the flow rate 30,000 Ltrs/hour. After dewatering, dirty water and sludge are removed with the help of a sludge pump.This is followed by cleaning of the walls and ceiling of the tanks with high-pressure jet, which dislodges the layer of dirt and algae. After cleaning of walls & roof, the floor of the tank is thoroughly cleaned by the high pressure water jet removing all the remaining dirt and algae. After removal of the sludge, dirt is vacuumed out using an Industrial Vacuum Cleaner. The sludge is then taken out of the tank and disposed off to a safe place. The same process is adapted for the overhead terrace tanks as well. In the final stage of the tank cleaning, UV Radiation is applied inside the tanks.
- Frequency of cleaning of the tanks are defined for particular area of the hospital. However, whenever there is growth in WS, frequency of cleaning is increased and actions taken promptly.
- ***Pall-Aquasafe water filter installation:*** As a temporary solution, Pall Aquasafe Water filters (AQ14F1R) were installed. The sterilizing membrane is validated at 0.2 µm and protects against waterborne particulates and pathogens as *Legionella spp.*, *Pseudomonas spp.* and fungi. These filters are compatible with upto 1.0 mg/L of ClO2 (1 ppm) at 60 or with 100 ppm free chlorine at ambient temperature.[19]
- ***Pipeline change:*** Finally pipelines were changed in OT when repeated cultures were showing growth despite all measures.

DISCUSSION

SSI accounts for 20% of all HAIs with 9-11 fold increased risk for mortality despite having advanced operating room ventilation, sterilization methods, barriers, surgical technique, and availability of antimicrobial prophylaxis.[20] Our study reveals 57% SSI out of all HAIs which is higher as compared to other literature in India (33%)[2], 20%[20]; this may be because SSI rates are not routinely documented in large number of HCOs all over the LMIC; official data on SSI is just the tip of the iceberg. Secondly out of all SSIs, 93.62% belonged to surgeries on immunocompromised cancer patients who are more prone for such infections. Moreover, surgeries on such patients were mostly categorized into clean-contaminated and contaminated surgeries keeping the risk of SSI on a higher side.(Fig 3a, 3b) The development of SSI is multi-factorial; it may be related to patient's risk factors such as age, sex, co-morbidity, smoking habit, obesity, nutrition level, immunosuppression, malignancies, transfusion etc. Environmental risk factors include level of microbial contamination, temperature, humidity, air renewal etc.[21, 22]

There are evidences since long that microbes can survive in hospital water reservoir; various studies have confirmed hospital water as a source of nosocomial infection.[7,23,24] Literature suggests relation of damp environmental reservoirs (sink drains, traps and the horizontal drainage system) with Multi-drug resistance (MDR) Gram-negative bacilli, including MDR coliforms.[21,25] *K. pneumoniae* demonstrating prolonged survival within plumbing components are also more likely to be extended spectrum β-lactamases (ESBL) producers.[26] There are many articles in favour of MDR *K. pneumoniae* persistently harboring in sink and related pipes leading to outbreaks in ICUs.[21, 27, 28, 29] In LMICs, inadequate chlorination is associated with high levels of water contamination which are linked to outbreaks by Enterobacteriaceae, including *Klebsiella spp.* and *Enterobacterspp*.[7] In our study, we found MDR-*Klebsiella pneumoniae* once in WS; 2 cases of SSI in that month was also shown growth of MDR-*Klebsiella pneumoniae. E. coli* is a type of fecal coliform bacteria commonly found in the intestines of animals and humans and the presence of it in water is a strong indication of recent sewage or animal waste contamination.[30] In our HCO, faecal *E. coli* was isolated once which was immediately taken care of. However, out of 5 cases of SSI, one had *E.coli* infection with same susceptibility pattern with that of isolate in water. No *Enterobacterspp* was isolated in WS.

Coliforms are known as the best index for monitoring water microbial quality; however, growth of coliforms can be inhibited by heterotrophic bacteria. Hence, as an alternative index in water microbial quality control, *Pseudomonas spp*. can be taken as one indicator.[31,23] Water of HCO can act as a reservoir for opportunistic pathogens like *Pseudomonas spp., Stenotrophomonas spp., Burkholderia cepacia, Acinetobacter spp*, fungi, etc. which pose a risk of colonization and infection for immunocompromised patients.[21,32] These organisms are known for biofilm formation on sinks, sink traps, pipes, water lines and hospital drains. These organisms residing in biofilms are resistant to the effect of chlorine and other disinfectants and antibiotics leading to Antimicrobial resistance (AMR).[20,32] Physical disruption of the biofilm lining the internal surfaces of affected water systems is the reliable method of cleaning.[21,34,35] Water related *Pseudomonas spp.* was the notorious microorganism in our study which was found in many SSIs simultaneously.

Modes of transmission includes direct contact, ingestion of water, indirect contact, inhalation of aerosols dispersed from water sources, and aspiration of contaminated water.[23,36] High levels of bacteria in hospital water, sinks, faucets, or shower heads has been associated with hand colonization.[18] Although there is no standardized limit of bacteriological clean water for surgical hand scrub, surgical hand antisepsis requires medicated soap with clean water to rinse the hands.[32] Thereafter, micro-perforations in the surgical gloves can lead to transmission of colonized microorganisms from the hands of the surgeon to the patient that happens at an average of 18% (5-82%) at the end of the surgery.[32,37] Double gloving decreases the risk of puncture during surgery, but punctures are still observed in 4% of cases after the procedure.[32,38] Therefore, continuous monitoring and surveillance of water quality is a real need in any HCO, with special reference to high risk areas like OT. Primarily being a cancer care organization along with transplants, we can't ignore any microorganism in WS culture from OT; for which various strategic multi-level actions were taken as soon as possible to reduce the rate of SSI.

CONCLUSION

Contaminated water system may contribute to HAIs by various pathogens like coliforms and other opportunistic pathogens. Stringent implementation of WS program along with immediate corrective action against the root cause of contamination should be mandatory in each HCO. *Pseudomonas spp.*, which causes opportunistic infections in immunocompromised patients was found to be the predominating resistant bug in our HCO. This bug was resistant to all cleaning efforts; finally pipelines had to be changed to get rid of this resistant organism along with stringent protocols of chlorination and tank cleaning. Re-contamination is not uncommon despite every effort; therefore routine policies are made for periodic surveillance of water with defined frequency in each high risk area of the HCO.

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