Implementation of Infection Control During Disaster

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Outlines

- Situations-based decision making
- How to best apply infection control concept during disaster?
- Lessons Learnt
- Conclusions

Natural disaster

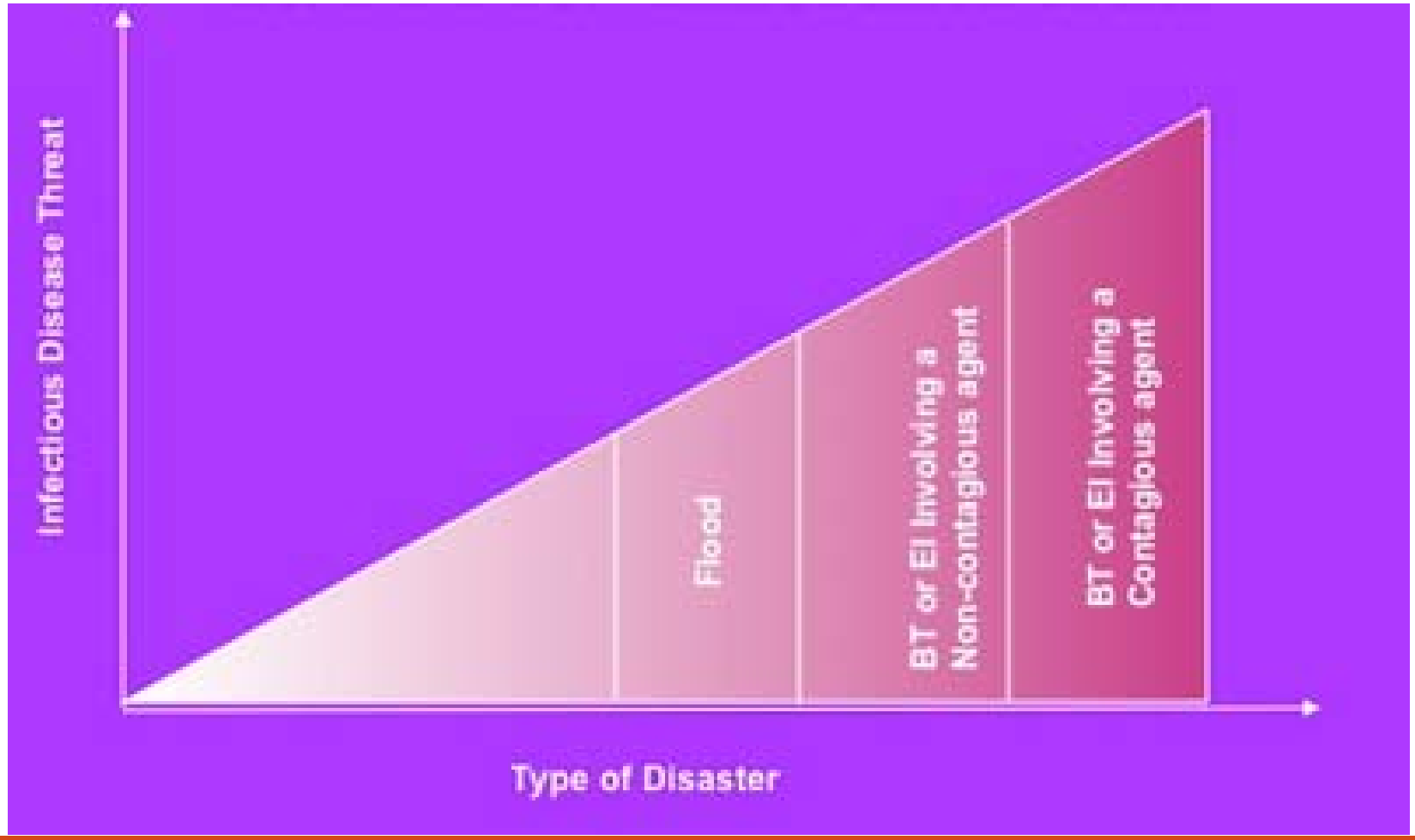
- Volcanic eruption
- Earthquake
- Cyclone of Hurricane
- Avalanche
- Flood & Tsunami
- Drought
- Forest fire of Bushfire
- Landslides
- Tidal wave
- Environmental pollution
- Snow storms
- Epidemic Disease

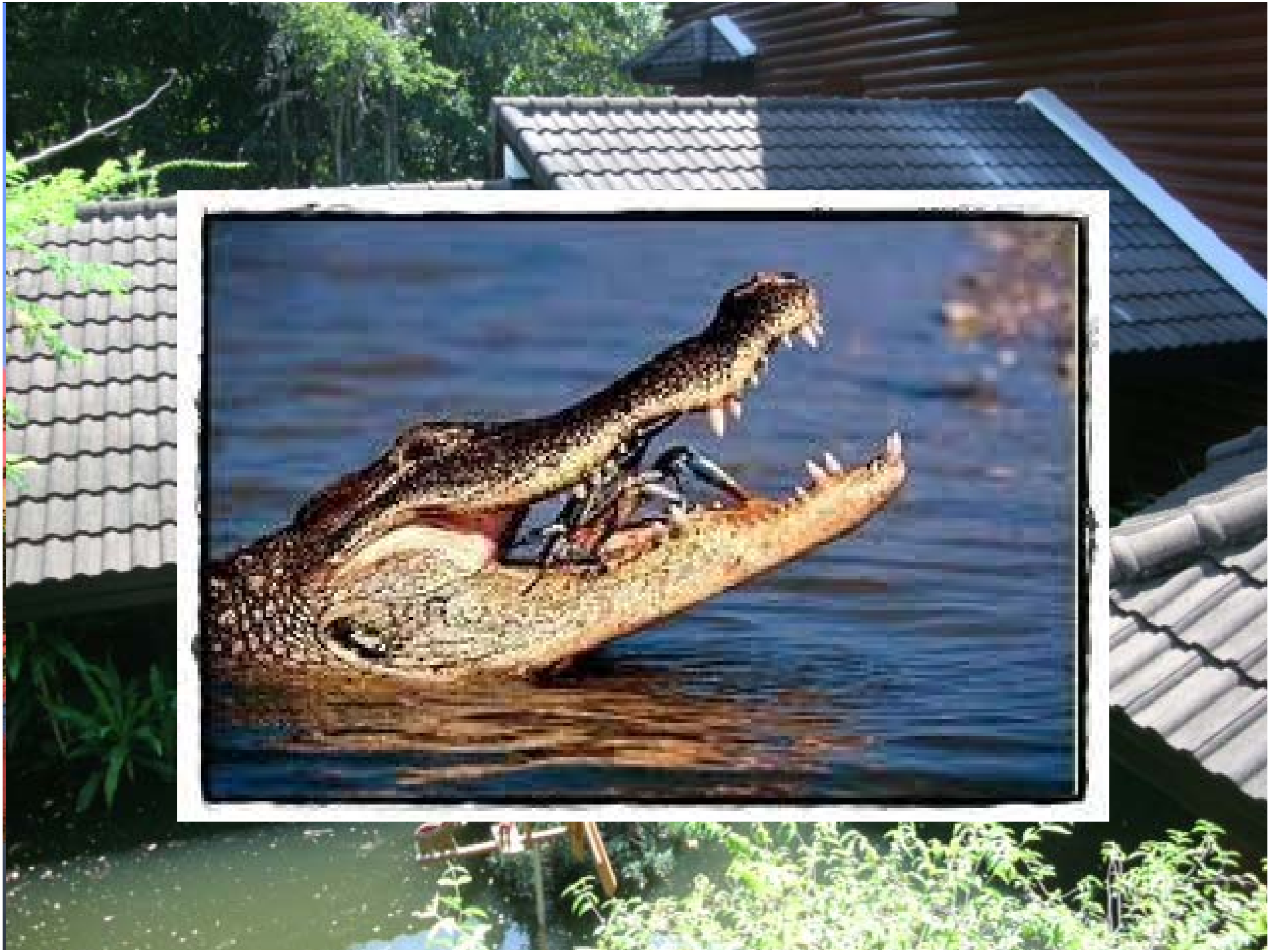
Political disaster

Political disaster

Disasters are Increasing

All disasters can have an impact on infection transmission





Hospital Structures from Initial Site Inspections

Hospital Pre- Vs. Post-

Soon after water removal process from the hospital has been completed, hospital administration would like to immediately open the clinical services.

What will be your response?

A) It is impossible to open service at this time. We should renovate the hospital before resume all clinical service. (6 months)

B) It is possible to open clinical services, but we need to renovate the hospital before. (3 months)

C) We can open the clinical service now with some minimal preparation time. (within 1 month)

Despite discussion the need to prepare the hospital before re-opening, hospital administration would like to open clinical services within 2 weeks after water removal.

What should be the first priority that you should do before re-open the clinical services?

A) Cleaning and disinfection the hospital units

B) Contain construction & renovation site

C) Evaluate HVAC system and area decontamination

D) Assess the burden of mold in the air and remediate the mold

E) A-D

F) A-C

Despite preparedness plan, fungal air sampling from several places still abundant!

How do you inform hospital administration?

A) High fungal bioburden will compromise patient safety…should give me more time to prepare.

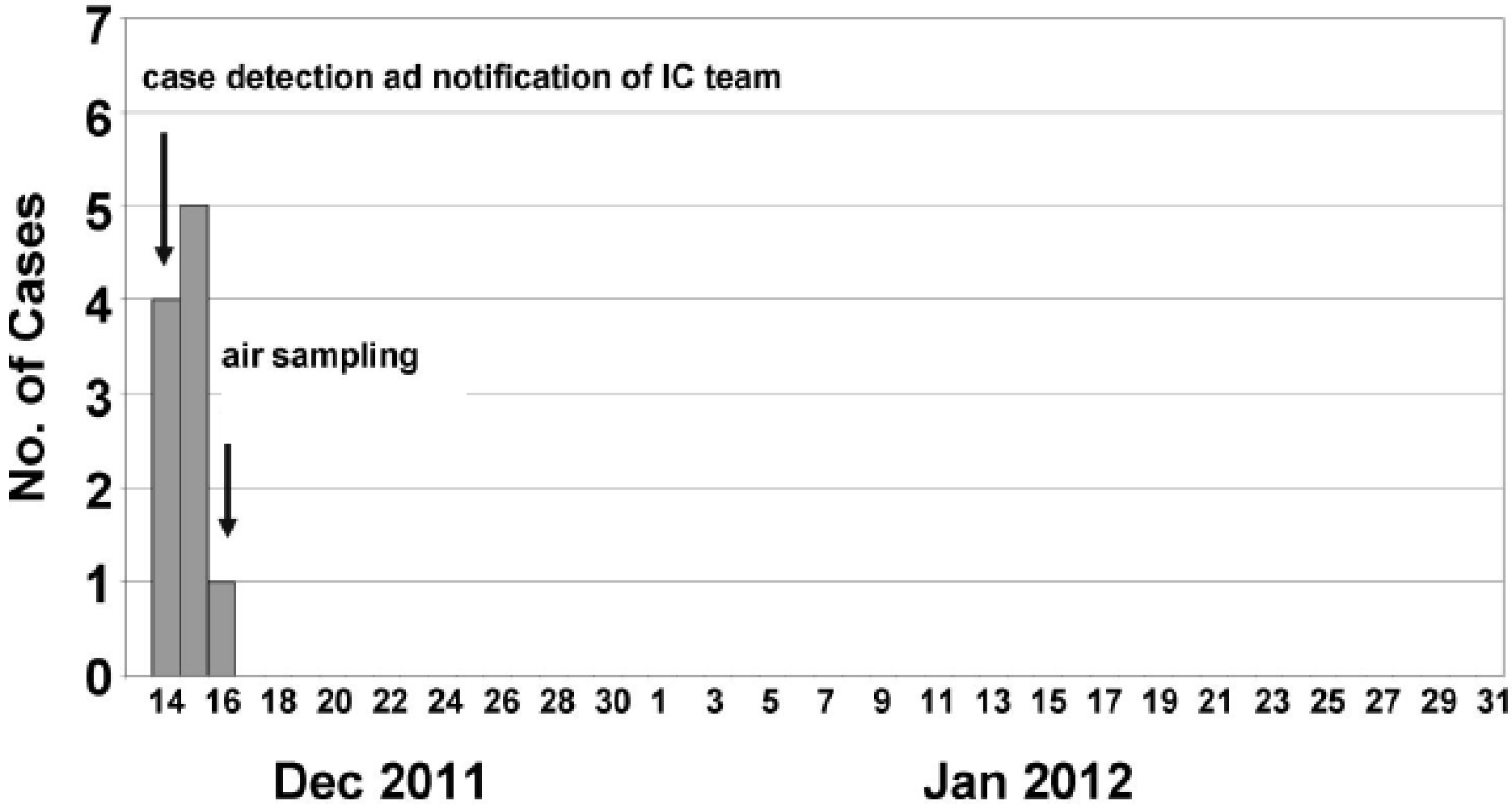
B) There is no standard on fungal bioburden. So, we can try to open the hospital.

C) There is no standard on fungal bioburden. We can monitor it over time to see the trend after we open the hospital.

Hospital administration insist that, in his view, hospital is safe enough to open.

AFTER HOSPITAL RE-OPEN FOR 2 DAYS….

Emergence of *Penicillium* spp. from hemocultures



What do you think this incident came from?

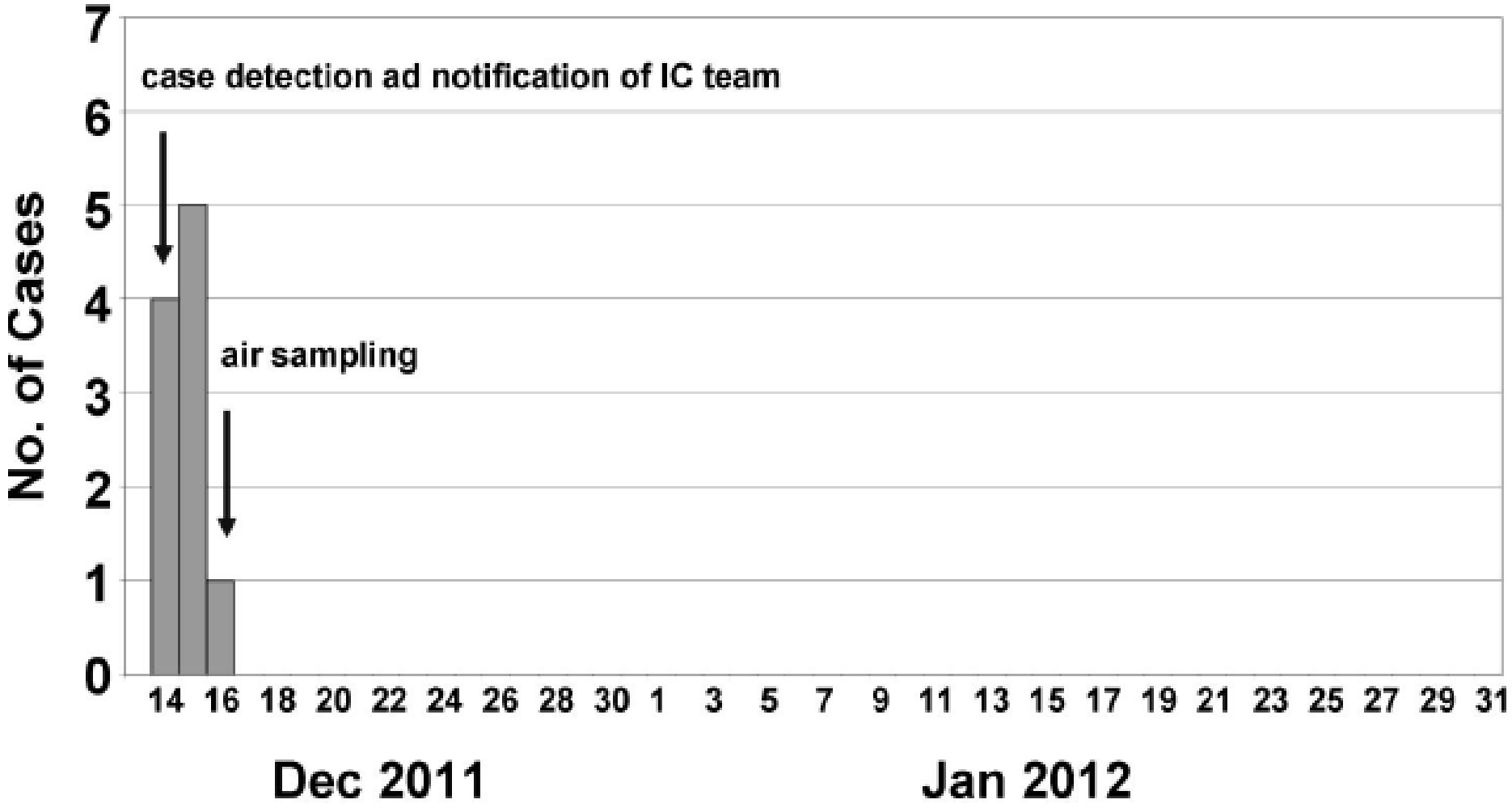
A) Possible a point source outbreak that need investigation

B) Possible pseudo-outbreak that do not need investigation

C) Possible pseudo-outbreak that need investigation

D) It came from environmental contamination

Emergence of Pseudo-outbreak due to *Penicillium* spp.



Obtaining Outbreak Data

Table 1. Demographic and Clinical Characteristics of 10 Hospitalized Patients With Postflood Pseudofungemia With *Penicillium* Species Identified During a 72-Hour Interval

Case	Age/Sex	Location Where BCs Were Drawn (Positive Sets)	Underlying Diseases	Final Diagnosis[a]	Hospital Length of Stay (d)
1	84/F	ED (1)	HTN	Aspiration pneumonia	4
2	54/M	ED (1)	None	CAP	2
3	5/M	ED (1)	None	Severe tonsillitis	1
4	65/M	ED (2)	None	CAP	2
5	76/F	ED (2)	HTN, DM	Viral gastroenteritis	1
6	45/F	ED (1)	DM	DKA	4
7	71/M	ED (1)	HTN, CVA	Viral syndrome	2
8	30/F	ED (2)	None	Dengue fever	2
9	36/M	ED (1)	None	Viral gastroenteritis	1
10	41/F	ED (1)	None	Leptospirosis	3

Postflood Pseudofungemia Due to *Penicillium* Species

Anucha Apisarnthanarak,[1] Thana Khawcharoenporn,[1] Kanokporn Thongphubeth,[1] Chananart Yuekyen,[1] Suwat Damnin,[2] Narissara Mungkornkaew,[3] and Linda M. Mundy[4]

CID 2012:55 (15 July)

Pseudo-outbreak may seem benign, but it is a big deal for some patient populations. It also impact physicians' decision.

What will you do in patients who will received hardware after surgery or CVT surgery?

It will impact doctors' decision to treat immunocompromised hosts (e.g., febreile neutropenia)

Fungal infections is also in differential diagnosis for NI in units with high fungal burden in the air

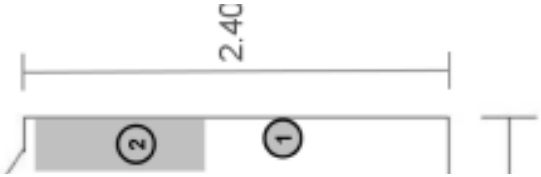
What we found from the field?

Air sampling in ER confirmed *Penicillium* species in the areas affected (1 area), but not other areas (3 areas)

Air sampling was performed in all units to prioritize the need for extra effort for mold re-mediation!

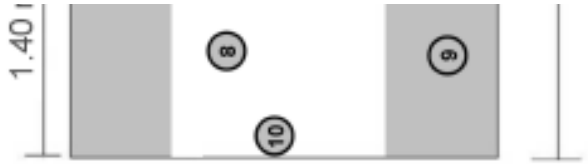
Decontamination of room air and adjoining wall surfaces by nebulizing hydrogen peroxide

GMS Krankenhaushygiene Interdisziplinär 2011, Vol. 6(1), ISSN 1863-5245



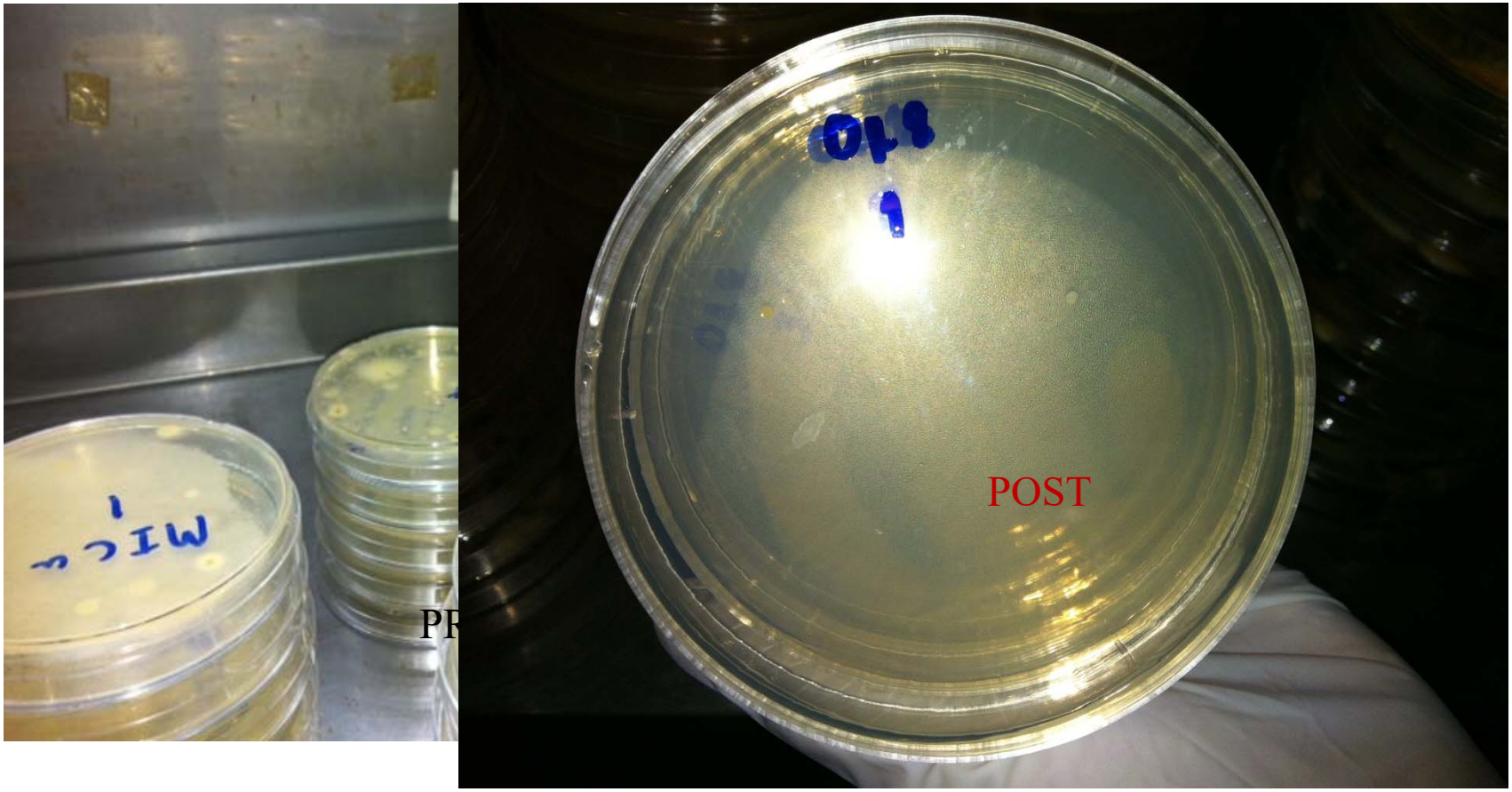
Results: In a massive mold infestation resulting from water damage (worst case), an approximately 9-fold decrease in the mold content and an approximately 13-fold decrease in the number of colony-forming units (sum of the bacteria + fungi) could be detected in the room air immediately after the nebulizing was finished. Even in samples of wall and joint plaster, the molds were reduced, although to a distinctly lesser extent.

By indoor nebulization of 5–6% H_2O_2, *A. brasiliensis* was reduced >4 log on vertical and horizontal surfaces.

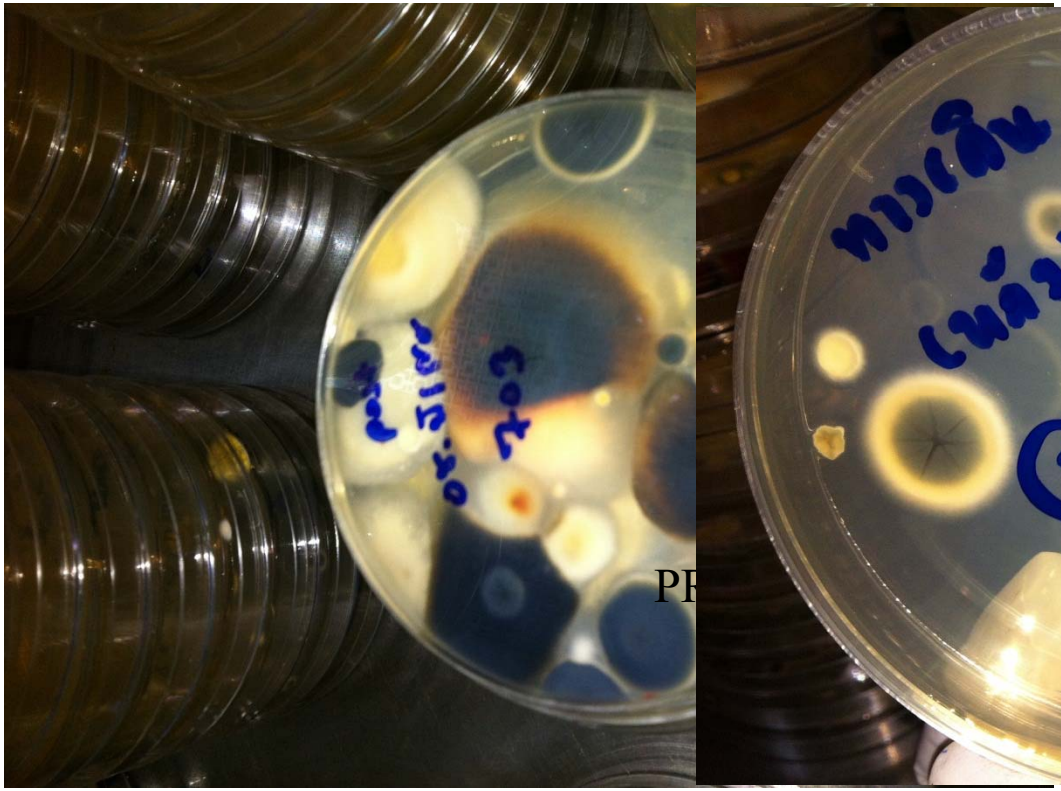


Introduction of HP

Outcomes (close units)



Outcomes (open units)



PRE

POST

Does Fumigation with Other Products Produce the same Results?

Table 1. Serial Air Bioburden Measurements of Bacteria and Fungi in the Patient Rooms and Nursing Station of a Hospital's Negative-Pressure Unit After Fumigation With a Quaternary Ammonium Salt–Based Solution Combined With 2 Alcohols

Duration After Fumigation	Bacterial Air Bioburden (CFU/m^3)					Fungal Air Bioburden (CFU/m^3)				
	PR 1	PR 2	PR 3	PR4	NS	PR1	PR2	PR3	PR4	NS
6 hours	840	660	580	680	900	534	553	585	536	556
Day 1	30	90	90	80	120	147	147	134	134	234
Day 7	30	90	120	120	200	147	130	147	100	234
Day 14	30	90	330	180	470	335	236	336	450	326

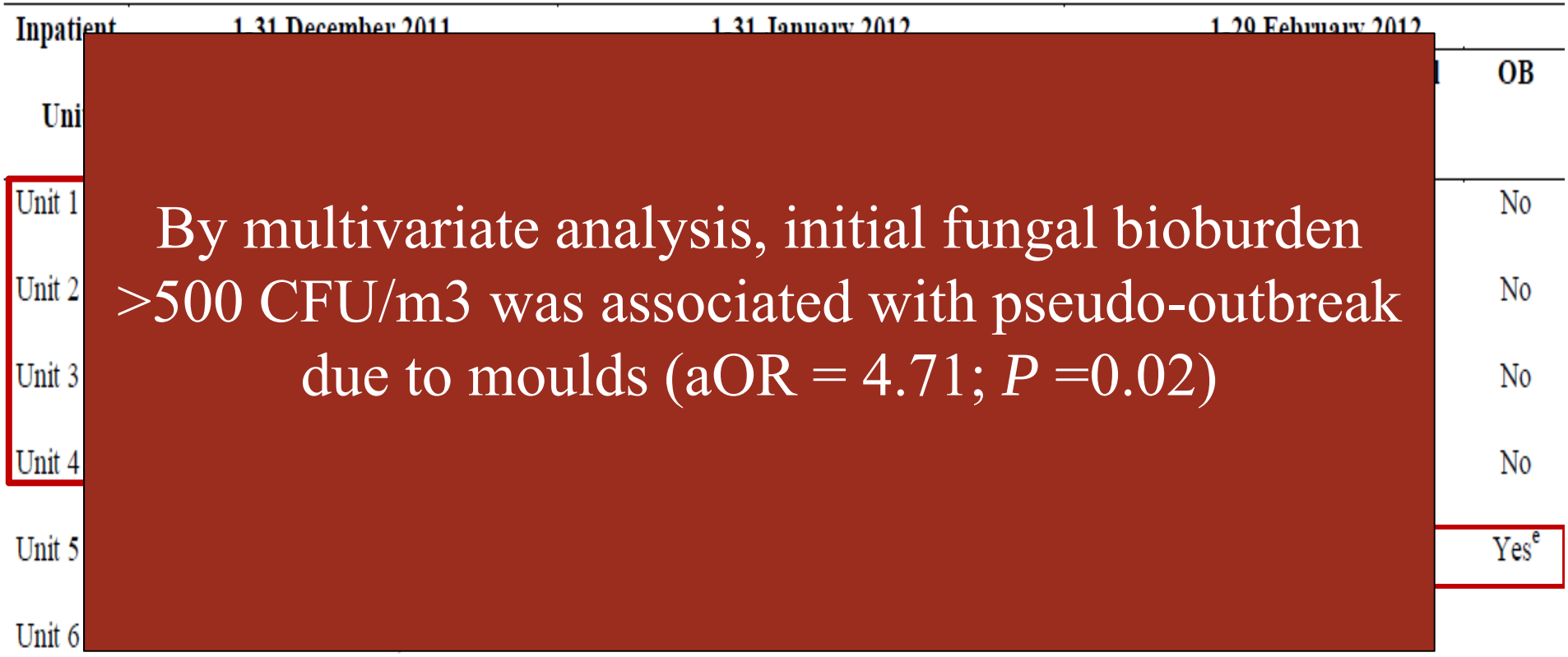
Abbreviations: CFU, colony-forming unit; NS, nursing station; PR, patient room.

Anucha Apisarnthanarak,[1] Sunee Wongcharoen,[1] and Linda M. Mundy[2]

[1]Division of Infectious Diseases, Faculty of Medicine, Thammasat University Hospital, Pathumthani, Thailand; and [2]GlaxoSmithKline, Collegeville, Pennsylvania

Six Outbreak Investigations for Moulds

Table 1. Investigation of cases with mold and air sampling measurements from six in-patient units after re-opening hospital.



By multivariate analysis, initial fungal bioburden >500 CFU/m3 was associated with pseudo-outbreak due to moulds (aOR = 4.71; *P* =0.02)

Apisarnthanarak A, et al. Blackwater flood and pseudo-outbreak. ICHE 2012

Figure 1

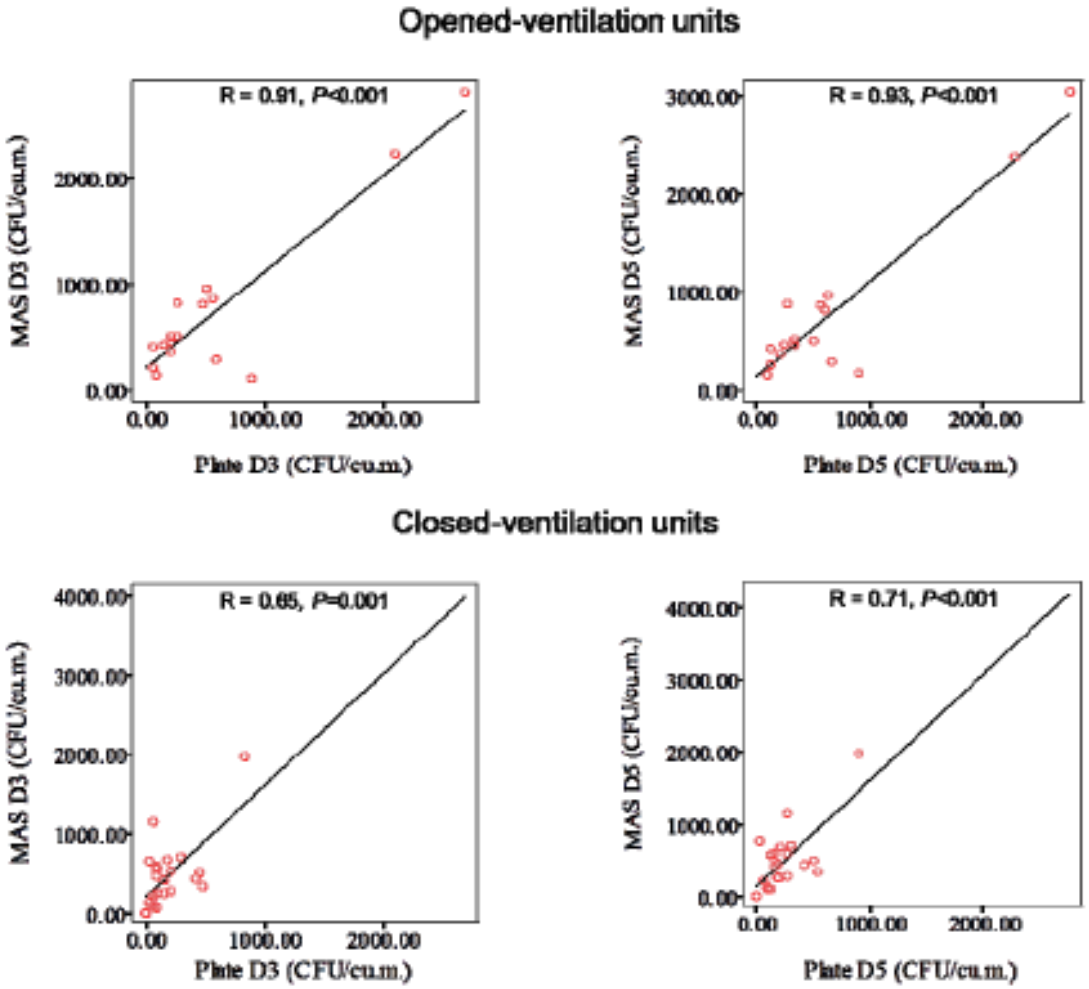

Opened-ventilation units
R = 0.91, P<0.001
MAS D3 (CFU/cu.m.)
Plate D3 (CFU/cu.m.)
R = 0.93, P<0.001
MAS D5 (CFU/cu.m.)
Plate D5 (CFU/cu.m.)
Closed-ventilation units
R = 0.65, P=0.001
MAS D3 (CFU/cu.m.)
Plate D3 (CFU/cu.m.)
R = 0.71, P<0.001
MAS D5 (CFU/cu.m.)
Plate D5 (CFU/cu.m.)

Table 3 Multivariate linear regression analysis for variables correlated with fungal bioaerosol results by microbiological air sampler method on day 3 and day 5

Variables	MAS D3				MAS D5			
	Opened-ventilation units		Closed-ventilation units		Opened-ventilation units		Closed-ventilation units	
	Adjusted coefficient (95% CI)	*P*	Adjusted coefficient (95% CI)	*P*	Adjusted coefficient (95% CI)	*P*	Adjusted coefficient (95% CI)	*P*
Plate D3	1.60 (1.12-2.07)	**<0.001**	-0.33 (-1.43-0.76)	0.49	--	--	--	--
Plate D5	--	--	--	--	1.49 (0.86-2.11)	**0.002**	-0.49 (-1.54-0.57)	0.30
Relative humidity	-81.83 (-236.72-73.06)	0.23	15.53 (-19.93-50.99)	0.33	-72.20 (-291.09-146.70)	0.44	18.10 (-19.15-55.35)	0.28
Temperature	154.37 (-340.26-649.00)	0.46	91.42 (17.36-165.47)	**0.02**	65.44 (-637.40-768.27)	0.82	104.32 (29.46-179.18)	**0.01**
Carbon dioxide	1.81 (-10.06-13.68)	0.71	-1.72 (-3.58-0.14)	0.06	-1.28 (-17.53-14.97)	0.85	-1.86 (-3.89-0.17)	0.07
Patient load	-2.06 (-4.56-0.43)	0.09	0.71 (-0.85-2.27)	0.31	-2.45 (-5.94-1.04)	0.13	0.77 (-0.81-2.35)	0.28
Nurse to patient ratio	-560.57 (-1768.95-647.82)	0.29	-15.31 (-116.58-85.97)	0.72	-1040.13 (-2697.80-617.54)	0.17	-28.82 (-139.64-82.01)	0.55

Table 4 Performance of settle plate method in comparison to microbiological air sampler method for identifying hospital units with unacceptable fungal bioaerosol level

Test performance	Results on day 3		Results on day 5	
	Opened-ventilation units	Closed-ventilation units	Opened-ventilation units	Closed-ventilation units
Sensitivity (%, 95% CI)	83.3 (43.6-99.1)	33.3 (10.3-51.2)	71.4 (37.3-93.9)	55.6 (26.8-77.7)
Specificity (%, 95% CI)	80.0 (56.2-89.4)	84.6 (68.7-97.0)	66.7 (40.1-84.2)	76.9 (57.0-92.3)
PPV (%, 95% CI)	71.4 (37.4-84.9)	60.0 (18.6-92.2)	62.5 (32.6-82.2)	62.5 (30.1-87.4)
NPV (%, 95% CI)	88.9 (62.4-99.4)	64.7 (52.5-74.2)	75.0 (45.1-94.7)	71.4 (52.9-85.7)

Lessons Learned

Use of air sampling periodically can help monitor the effectiveness of interventions and prioritize need for extra effort!

Air decontamination using vapor/aerosolize is only a part of room decontamination and cannot be used as stand-alone intervention

Other interventions that might help include through cleaning, use of filter/HEPA filter/UV light

One week later, hospital administration said that is now ready to open outpatient department. Hospital structure is not much improved, but become more clean.

How do you come up with strategy to handle significant patients influx in a relatively short space?

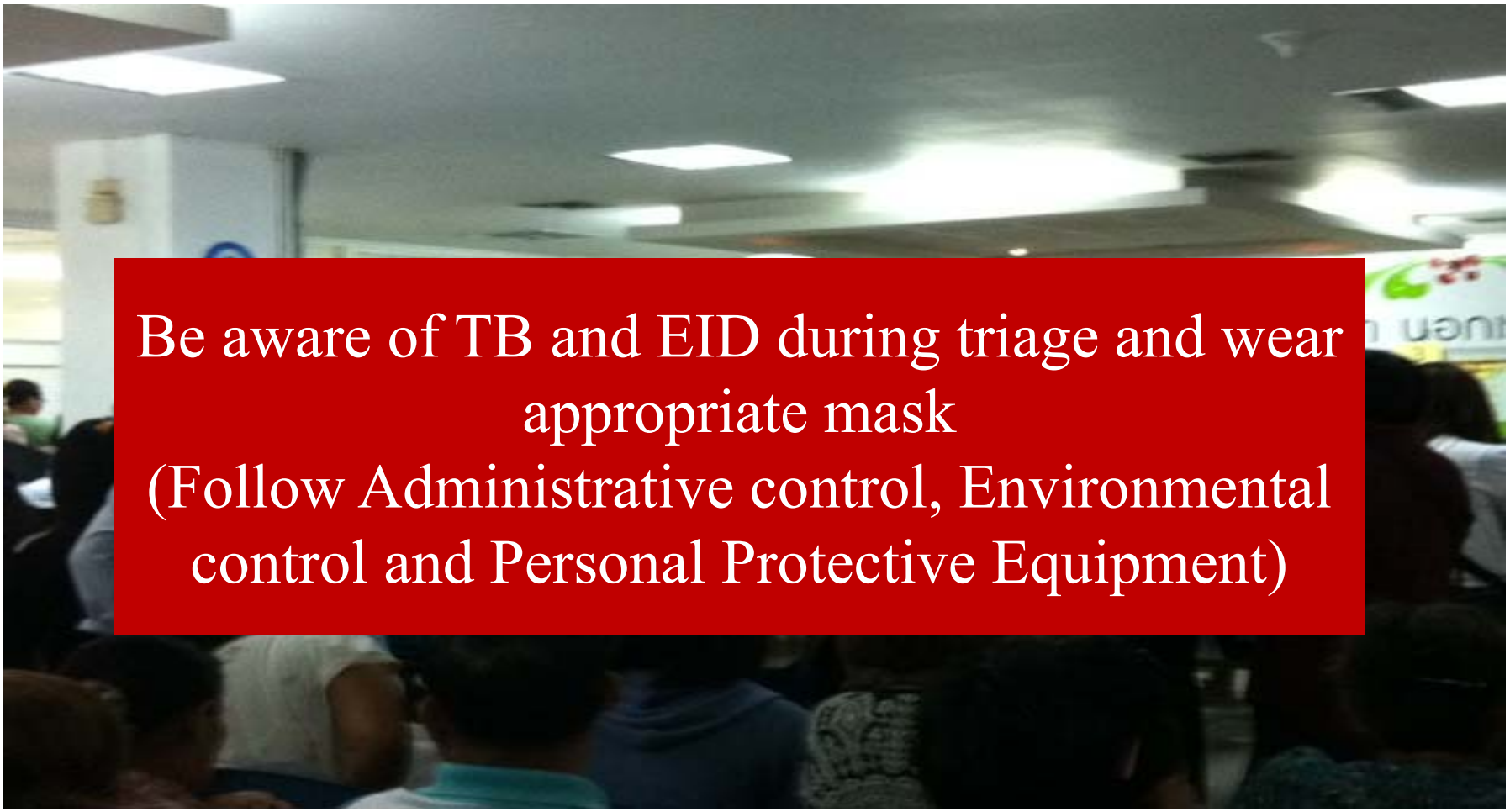
A) Inform hospital administration that we are not ready yet.

B) Set up an open air triage area

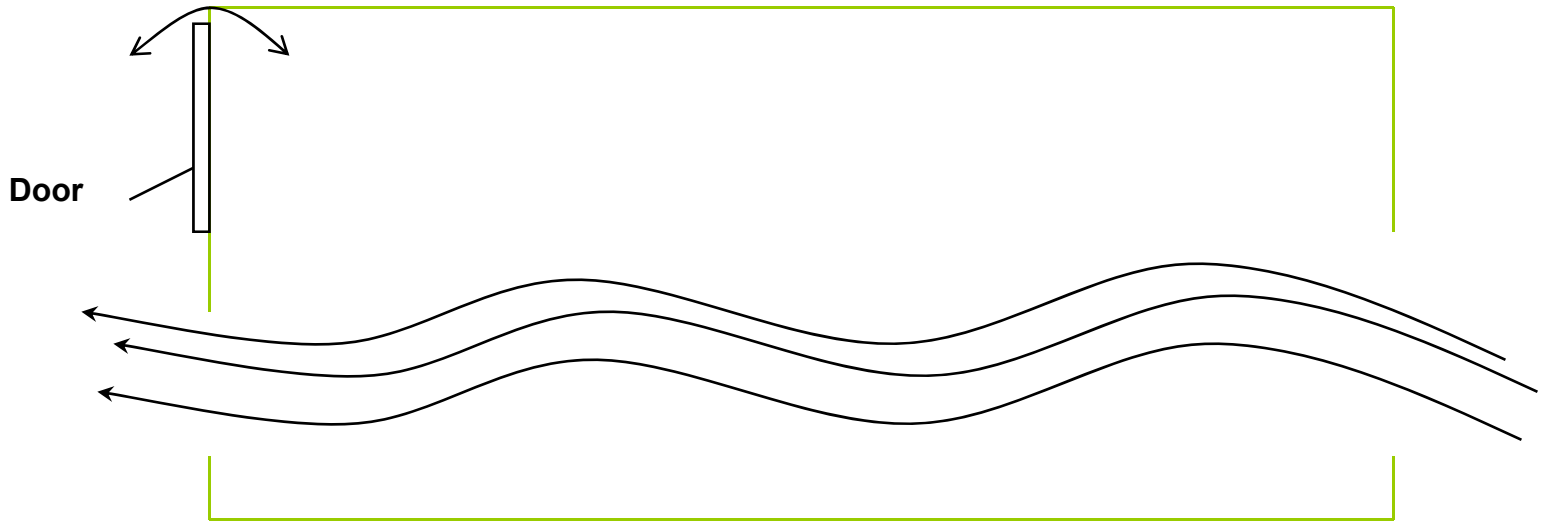
C) Use natural ventilation and monitor air flow periodically

D) B-C

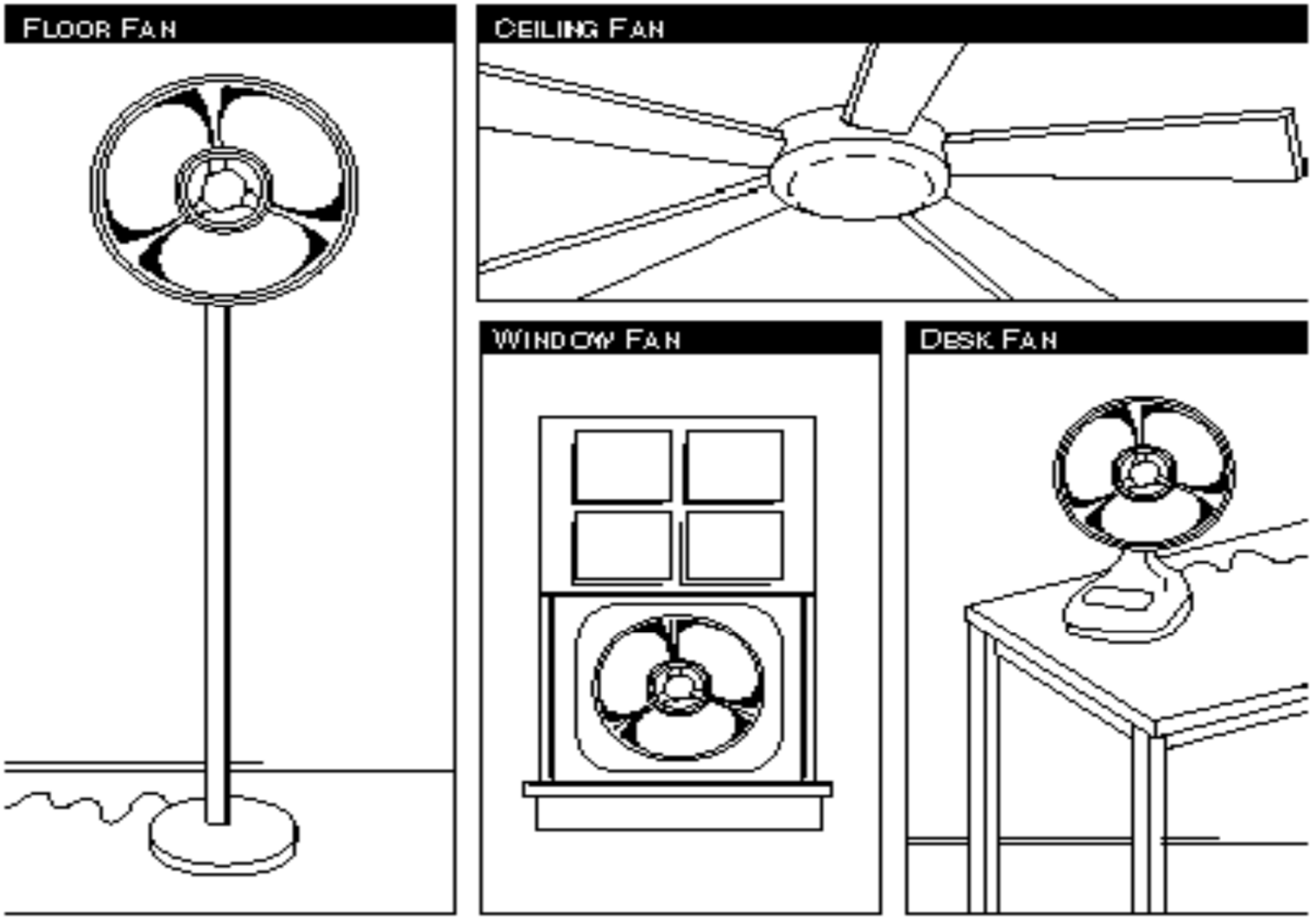
Triage in Crowded Area (2,000 visit at OPD and ER)

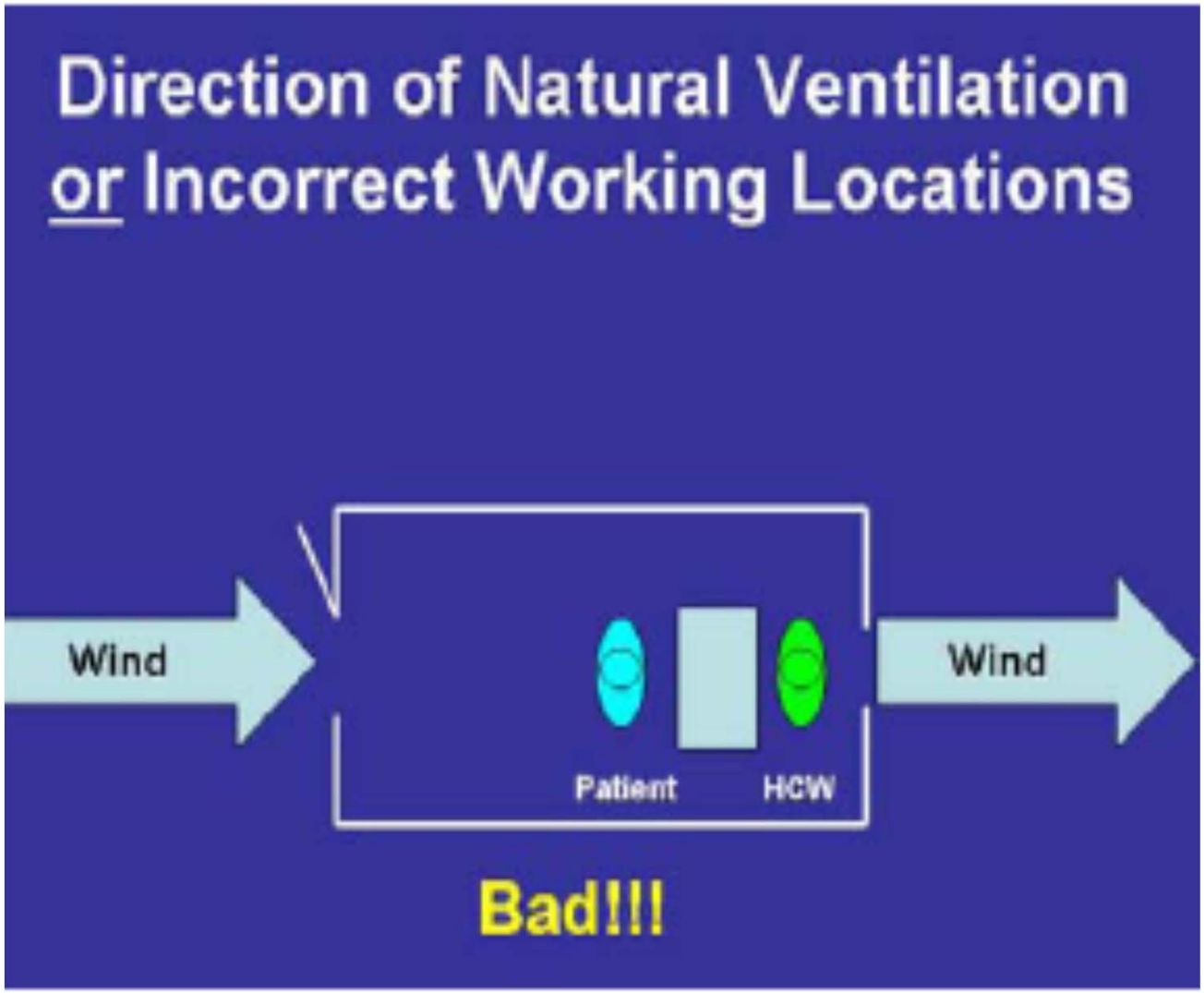


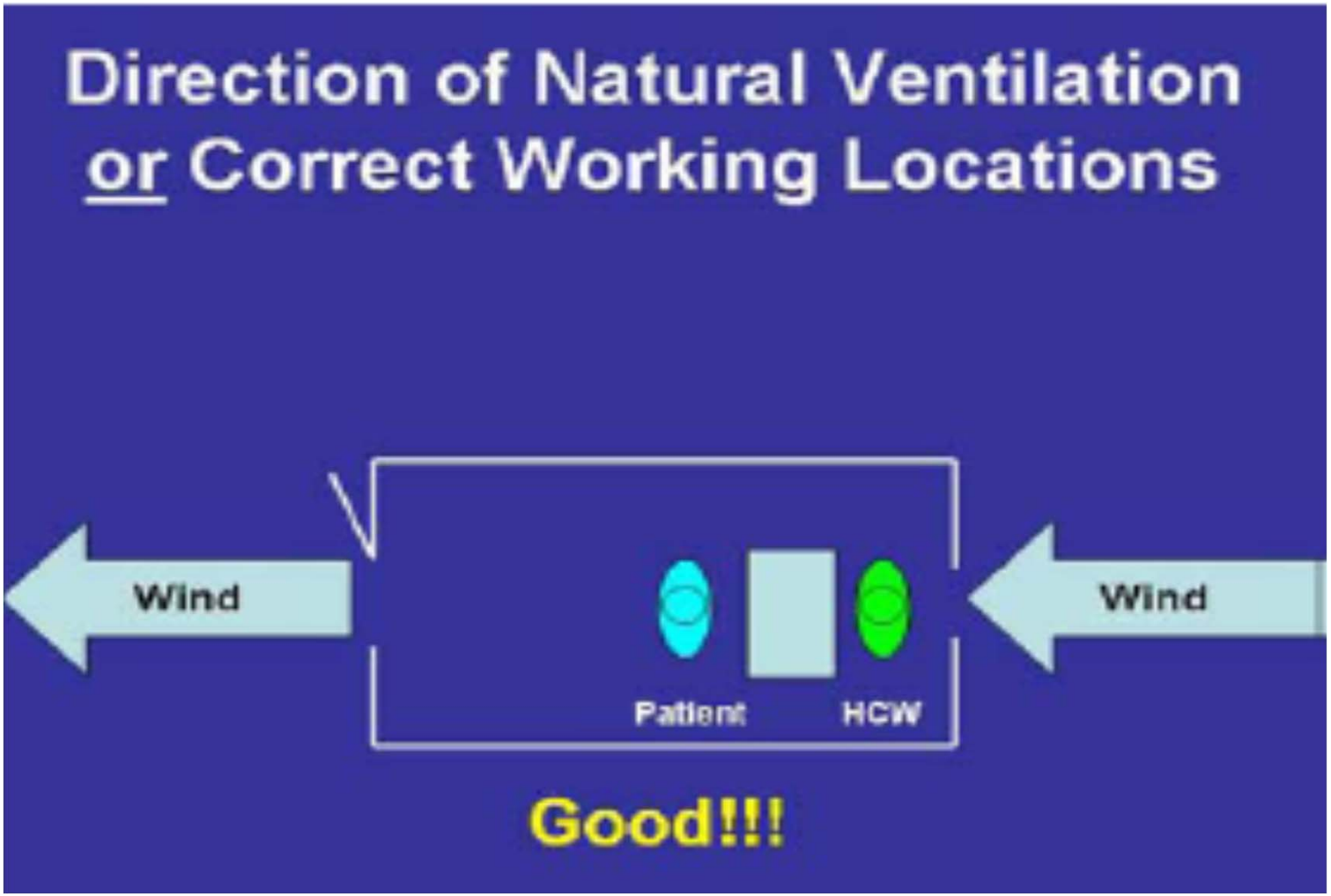
Natural Ventilation



Air Mixing and Directional Flow




Direction of Natural Ventilation
or Incorrect Working Locations
Wind
Wind
Patient
HCW
Bad!!!


Direction of Natural Ventilation
or Correct Working Locations
Wind
Wind
Patient
HCW
Good!!!

It is So HOT During Summer

Things to Consider: Always Test for Efficacy

Things to Consider: Always Test for Efficacy

Consider mechanism to avoid air cross contamination

At 4-weeks after hospital re-opening, there are influx of cases occur. Units that re-opened start to increase.

What kind of surveillance do you need to establish?

A) Surveillance for HAIs

B) Surveillance for MDROs

C) Active laboratory surveillance for water borne infections (e.g., NTM, Legionella, etc)

D) Surveillance for use of antibiotics

Surveillance After Flood

Traditional diseases:

- Leptospirosis
- Hepaitits A
- Dengue hemorrhagic fever
- Pneumonia (e.g., Legionella)
- Measle
- TB
- Infected conjunctivitis
- Viral diarrhea

Always monitors for possible diseases after flood

- We identified 5 cases of melioidosis occurred in a month after flood (melioidosis never thought to be related to diseases after flood)

- Unique feature of these patients: No traditional underlying diseases, quick presentation (within 5 days), high melioid titer and had fulminant clinical course

Apisarnthanarak A, et al. IJID 2012

Table 1

Clinical characteristics, laboratory data, and treatment outcomes of four patients with melioidosis associated with flood exposure

Case	Underlying conditions/diagnosis	*Burkholderia pseudomallei* IHA titer[a]	Days from presentation to admission: median	Days from admission to receipt of appropriate antibiotics: median	Treatment	Survived
1	COPD, HTN/CAP	1:2048	2	2	Imipenem	Yes
2	None/CAP	1:4096	5	2	CAZ + TMP-SMX	Yes
3	None/aspiration pneumonia	1:8192	5	2	CAZ + TMP-SMX	Yes
4	None/aspiration pneumonia	1:4096	5	2	CAZ + TMP-SMX	Yes
5	None/skin and soft tissue infection	1:2048	7	4	CAZ + TMP-SMX	Yes

IHA, indirect hemagglutination assay; COPD, chronic obstructive pulmonary disease; HTN, hypertension; CAP, community-acquired pneumonia; CAZ, ceftazidime; TMP-SMX, trimethoprim-sulfamethoxazole.

[a] Positive if >1:80 for persons residing in non-endemic regions.

Healthcare Associated Infections After Flooding

MYCOBACTERIAL INFECTIONS

Outbreak of *Mycobacterium porcinum* linked to water supply

M. porcinum is a rapid-growing mycobacterium

UTMB found 26 patients between 2005-2010

- Most cases before hospital flooding
- 11 patients considered infected (4 community and 7 hospital-acquired)
- Hospital water and ice samples collected immediately after flooding
  - 86 (62%) of 139 water samples grew rapid-growing mycobacterium – of those tested 50% were *M. porcinum*

M. porcinum detected in tap water from 80% of homes tested in same city as hospital

The majority of patient isolates were closely related to hospital and residential water isolates by PFGE

Brown-Elliott BA et al. *J Clin Microbiol*. 2011;49:4231-8.

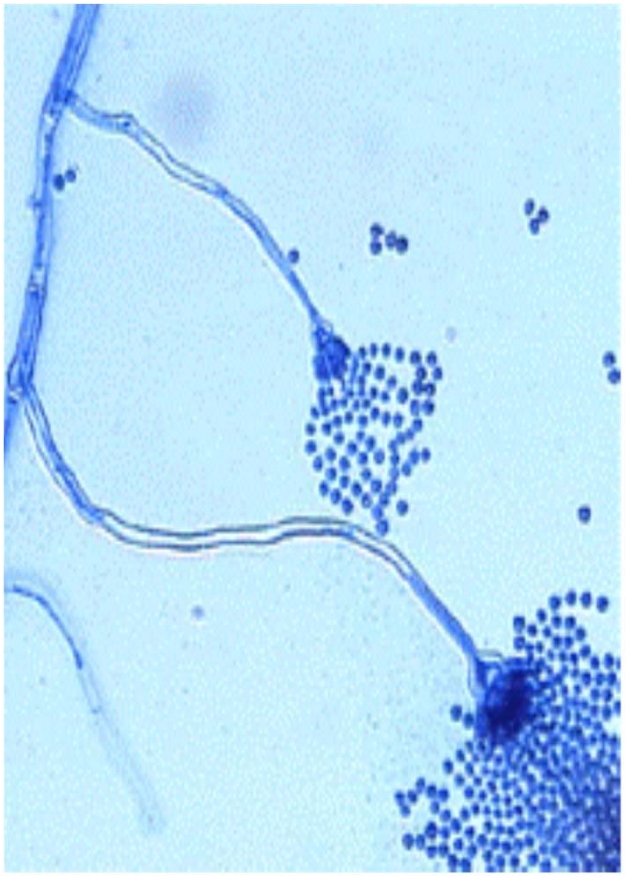
Invasive Infections: Aspergillus

Ubiquitous fungi

- *Aspergillus fumigatus* (90% of disease)

High risk patients

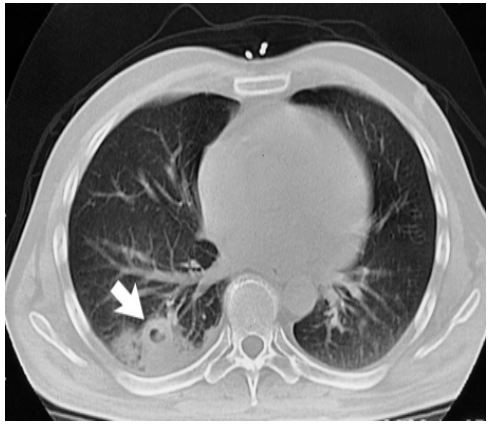
- Hematopoietic stem cell transplant recipients
- Solid organ transplant patients
- Prolonged neutropenia
- Preterm neonates



Stem Cell Transplant Units and Aspergillus Outbreaks

Causes

- no HEPA filtration
- poor maintenance of air filters
- poorly sealed windows and walls
- positive pressure not maintained
- no patient precautions when outside of unit
- construction in or near hospital
- disturbance of normally closed spaces
- often unknown



Surgical site infections and *Aspergillus spp.*

Examples in literature

- Endocarditis or aortitis following cardiac surgery
- Burn wound infections
- Prosthetic joint replacement
- Vascular grafts

Source of aspergillus not always known

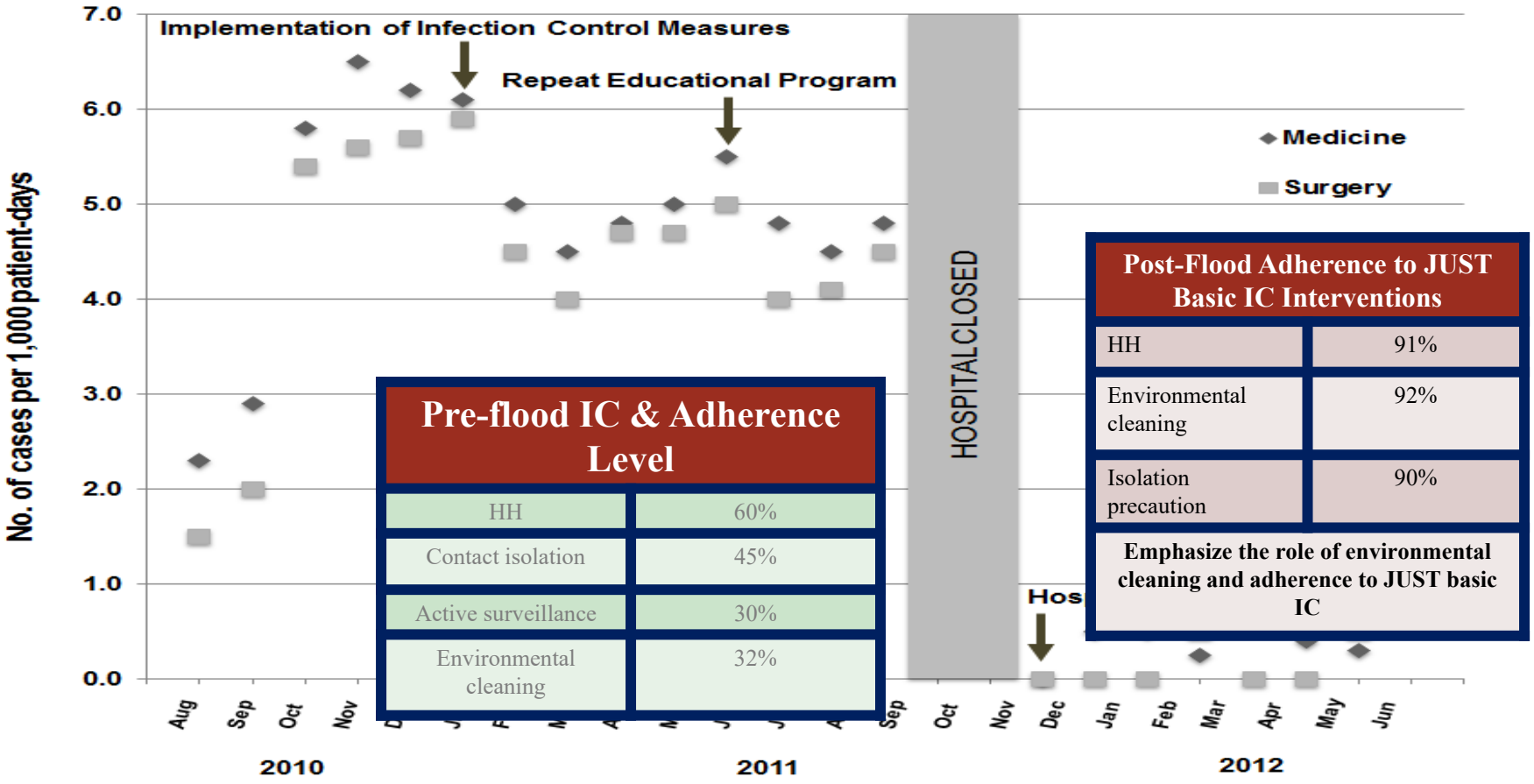
- Heavy contamination of OR air intake
- Contamination of insulation or air filters
- Contaminated irrigating fluids or wound dressings

Pasqualotto AC and Denning DW. Clin Microbiol Infect. 2006;12(11):1060-76

Healthcare Associated Infections After Flooding

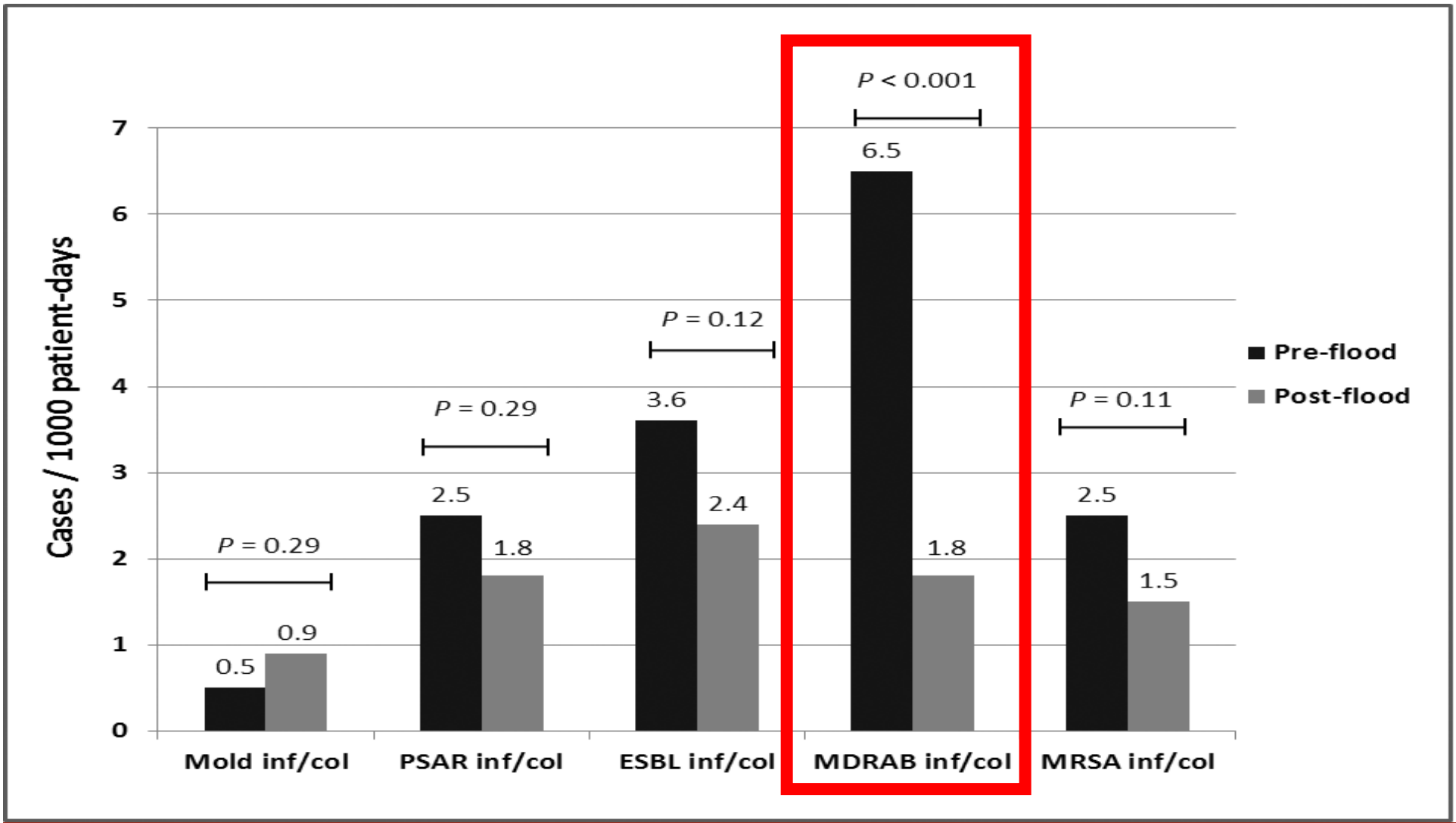
BACTERIAL INFECTIONS

Termination of XDR-Acinetobacter: Lessons Learned



Apisarnthanarak A, et al. Termination of XDR-AB after flood. CID 2012

This is Not a Local Issues: A Survey Was Made to 101 Hospitals in 15 Provinces



Apisarnthanarak A, et al. Patterns of NI, MDRO, molds after flood: a survey from central Thailand. ICHE 2013

Healthcare-associated infections and their prevention after extensive flooding

Anucha Apisarnthanarak[a], *David K. Warren*[b], *and C. Glen Mayhall*[c]

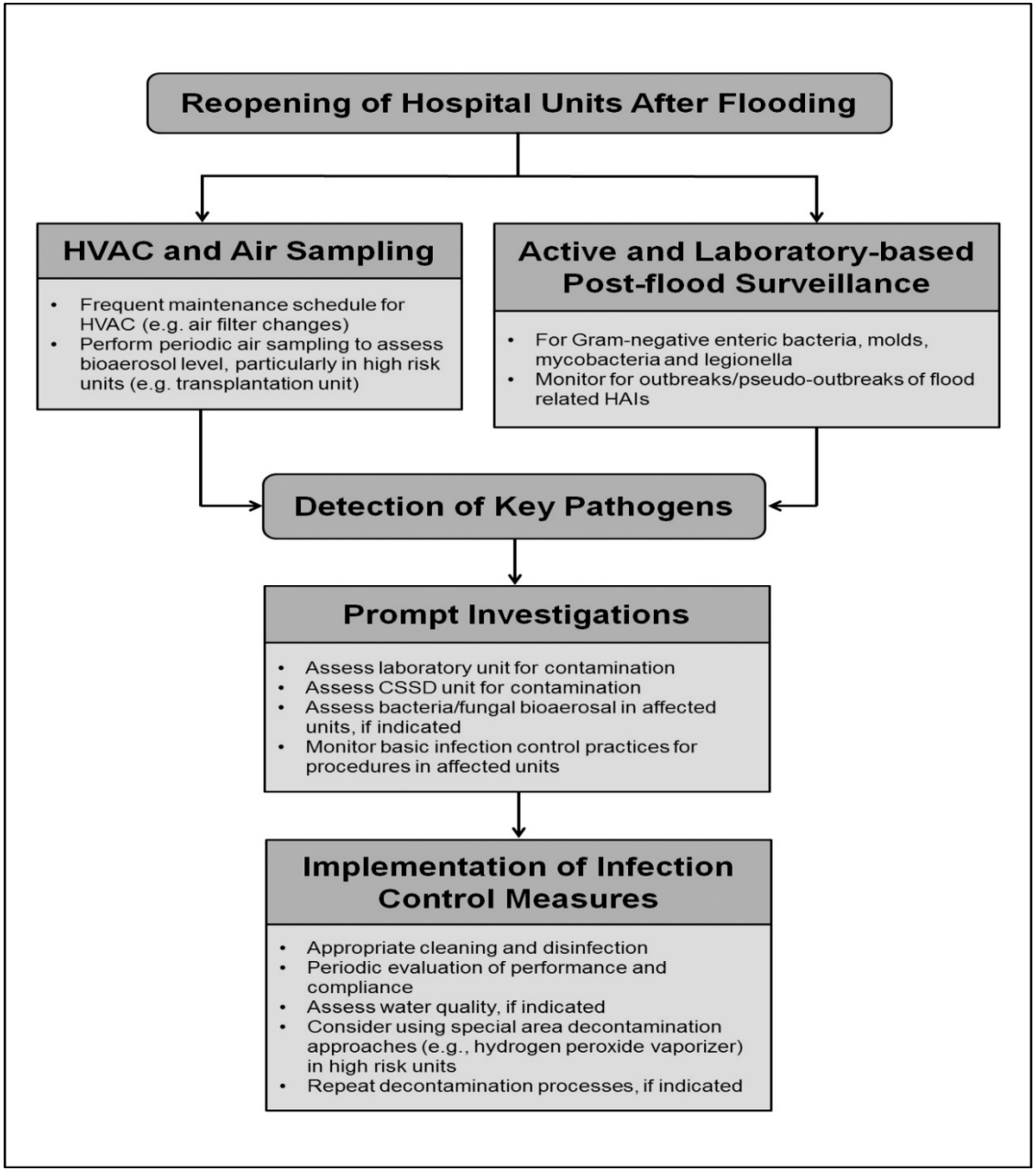
Purpose of review
This review will focus on the epidemiology of healthcare-associated infections (HAIs) after extensive blackwater flooding as well as preventive measures.

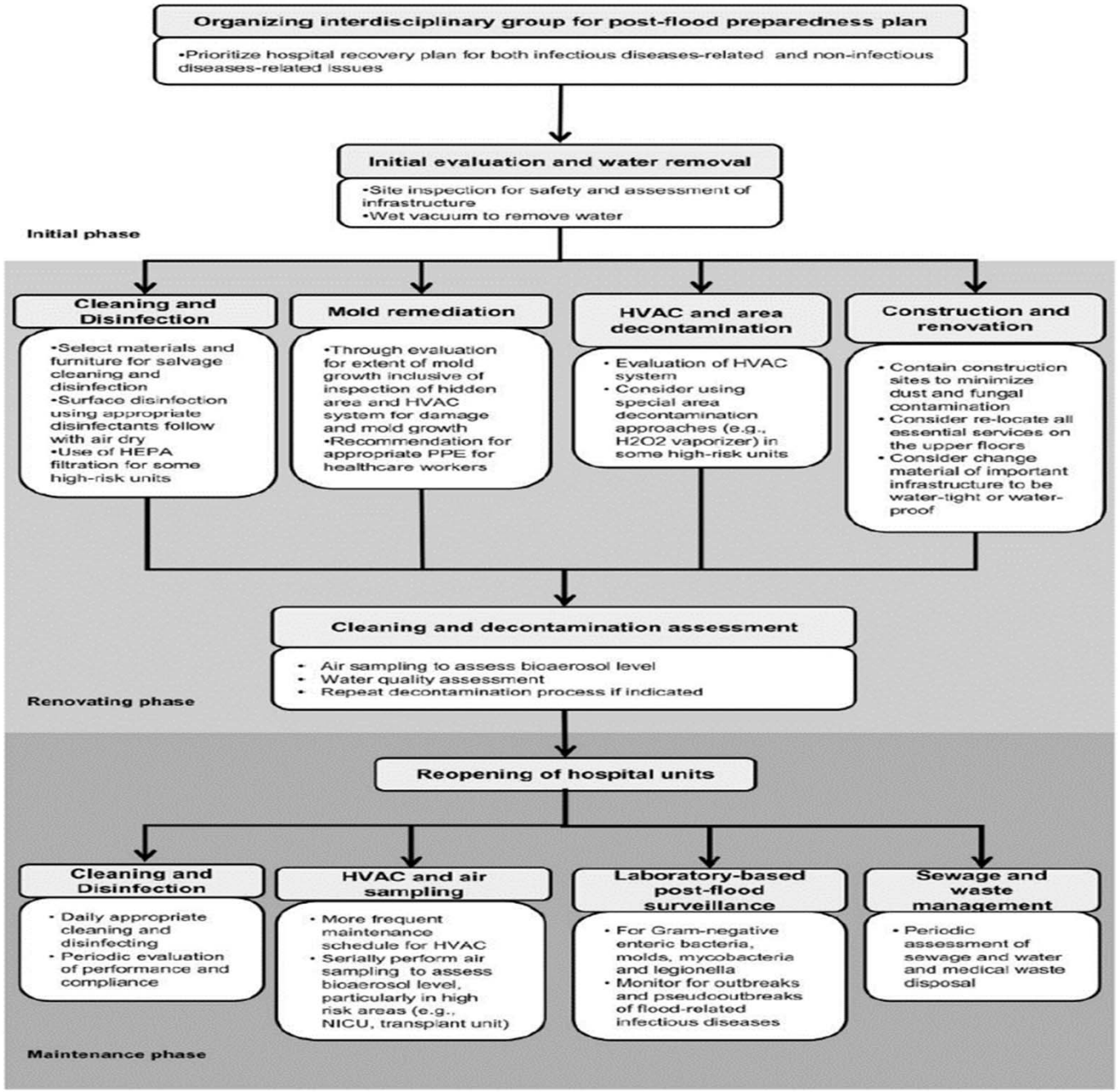
Recent findings
There is evidence suggesting an increased incidence of HAIs and pseudo-outbreaks due to molds after extensive flooding in healthcare facilities. However, there is no strong evidence of an increased incidence of typical nosocomial infections (i.e., ventilator-associated pneumonia, healthcare-associated pneumonia, central line-associated bloodstream infection and catheter-associated urinary tract infections). The prevalence of multidrug-resistant organisms may decrease after extensive flooding, due to repeated and through environmental cleaning prior to re-opening hospitals. Contamination of hospital water sources by enteric Gram-negative bacteria (e.g., *Aeromonas* species), *Legionella* species and nontuberculous *Mycobacterium* species in flood-affected hospitals has been reported. Surveillance is an important initial step to detect potential outbreak/pseudo-outbreak of HAIs. Hospital preparedness policies before extensive flooding, particularly with environmental cleaning and mold remediation, are key to reducing the risk of flood-related HAIs. These policies are still lacking in most hospitals in countries that have experienced or are at risk for extensive flooding, which argues for nationwide policies to strengthen preparedness planning.

Summary
Additional studies are needed to evaluate the epidemiology of flood-related HAIs and the optimal surveillance and control methods following extensive flooding.

Table 1. Organisms resulting in healthcare-associated infections after extensive flooding, risk factors and preventive measures

Type of organism/references	Specific pathogens	Risk factors	Preventive measures
Bacteria [12–14,23,24▪▪]	Water borne enteric GNB (e.g., *Aeromonas* spp., *Vibrio* spp.)	Contamination of water source	Periodic portable water quality assessment and investigation for point source, if indicated
		Contamination of internal plumbing	Environmental cleaning
		Contaminated wound	
	Legionella spp.	Contamination of water source	Periodic portable water quality assessment and investigation for point source
		Contamination of internal plumbing	Remediate with chlorine dioxide and then copper–silver ionization of water sources
	MDROs[a]	Hospital with lack of environmental cleaning policy	Repeated and through environmental cleaning
		Lapses in basic infection control practices	Consider using special approaches (e.g., hydrogen peroxide vaporizer) in high risk units
Mycobacterium spp. [25–29]	*Nontuberculous Mycobacterium* spp.	Contamination from laboratory	Periodic water quality assessment
		Contamination of water source	Remove contaminant from water source, if detected
		Contamination of ice machine and drinking water	Prompt investigation after case detection
		Contamination in patient sputum	
Molds [35–37]	Environmental molds (e.g., *Aspergillus* spp., *Penicillium* spp., *Fusarium* spp.)	High fungal air bio-burden	Repeated and through environmental cleaning
		No HEPA filtration	Serial monitoring of fungal air bio-burden
		Contaminated HVAC system	Consider using special approaches (e.g., hydrogen peroxide vaporizer) in high risk units
		Poor maintenance of air filtration	Contain construction sites
		Construction/Demolition in/near hospital	Scheduled maintenance for HVAC/HEPA system


Reopening of Hospital Units After Flooding
HVAC and Air Sampling
• Frequent maintenance schedule for HVAC (e.g. air filter changes)
• Perform periodic air sampling to assess bioaerosol level, particularly in high risk units (e.g. transplantation unit)
Active and Laboratory-based Post-flood Surveillance
• For Gram-negative enteric bacteria, molds, mycobacteria and legionella
• Monitor for outbreaks/pseudo-outbreaks of flood related HAIs
Detection of Key Pathogens
Prompt Investigations
• Assess laboratory unit for contamination
• Assess CSSD unit for contamination
• Assess bacteria/fungal bioaerosal in affected units, if indicated
• Monitor basic infection control practices for procedures in affected units
Implementation of Infection Control Measures
• Appropriate cleaning and disinfection
• Periodic evaluation of performance and compliance
• Assess water quality, if indicated
• Consider using special area decontamination approaches (e.g., hydrogen peroxide vaporizer) in high risk units
• Repeat decontamination processes, if indicated


Organizing interdisciplinary group for post-flood preparedness plan
•Prioritize hospital recovery plan for both infectious diseases-related and non-infectious diseases-related issues
Initial evaluation and water removal
•Site inspection for safety and assessment of infrastructure
•Wet vacuum to remove water
Initial phase
Cleaning and Disinfection
•Select materials and furniture for salvage cleaning and disinfection
•Surface disinfection using appropriate disinfectants follow with air dry
•Use of HEPA filtration for some high-risk units
Mold remediation
•Through evaluation for extent of mold growth inclusive of inspection of hidden area and HVAC system for damage and mold growth
•Recommendation for appropriate PPE for healthcare workers
HVAC and area decontamination
• Evaluation of HVAC system
• Consider using special area decontamination approaches (e.g., H2O2 vaporizer) in some high-risk units
Construction and renovation
• Contain construction sites to minimize dust and fungal contamination
• Consider re-locate all essential services on the upper floors
• Consider change material of important infrastructure to be water-tight or water-proof
Cleaning and decontamination assessment
• Air sampling to assess bioaerosol level
• Water quality assessment
• Repeat decontamination process if indicated
Renovating phase
Reopening of hospital units
Cleaning and Disinfection
• Daily appropriate cleaning and disinfecting
• Periodic evaluation of performance and compliance
HVAC and air sampling
• More frequent maintenance schedule for HVAC
• Serially perform air sampling to assess bioaerosol level, particularly in high risk areas (e.g., NICU, transplant unit)
Laboratory-based post-flood surveillance
• For Gram-negative enteric bacteria, molds, mycobacteria and legionella
• Monitor for outbreaks and pseudooutbreaks of flood-related infectious diseases
Sewage and waste management
• Periodic assessment of sewage and water and medical waste disposal
Maintenance phase

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Hospital floods highlight need for infection prevention, control

Apisarnthanarak A. *Infect Control Hosp Epidemiol* 2013;34:200-206
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Hospital closures after extensive flooding in Thailand and United States have brought attention to the need for hospital preparedness to ensure a safe environment in hospitals when they reopen.

"There are no existing data on hospital preparedness, which posed a problem when we first encountered extensive flooding," **Anucha Apisarnthanarak, MD,** of the division of infectious diseases at Thammasat University Hospital in Pratumthani, Thailand, told *Infectious Disease News*. "We think that sharing our experience would help others deal with hospital preparedness after floods."

Infection prevention and control strategies are necessary to safely reopen hospitals after flooding. These plans require expertise from various disciplines, including infection prevention and control personnel. There are four infection prevention and control issues to consider: removal of flood waters, disinfection, mold remediation and restoration of adequate air flow.

After identifying the water source, the water should be pumped out. The water types include clear water, which is water from the tap or rain; gray water, which is water from sinks, showers, tubs and washers; and black water, which is water contaminated with waste from humans and animals. After the water is pumped out, remaining water should be removed with wet vacuum. Items should be inspected for water damage and discarded if necessary.

Depending on the flood water type, cleaning and disinfection should commence. Nonporous materials and semiporous items can be cleaned, but porous materials should be discarded if exposed to black water. Surfaces should be disinfected with a bleach solution and followed by air drying and high-efficiency particulate air vacuum. Evaluations should be done to examine mold damage, and affected materials should be cleaned or discarded.

Lastly, the heating, ventilation and air conditioning (HVAC) system must be examined for mold, debris and dampness. Air samples must be taken to determine HVAC contamination.

"We need to do more study on hospital flood preparedness and lessons learned from previous floods," Apisarnthanarak said. "After the Thai floods of 2011, we found that most hospitals had a plan written, but very few exercised that plan. Research should include assessing preparedness plans on a national scale, evaluating diseases associated with floods in the community and appropriate infection control preparedness plans in resource-limited settings."

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Disclosure: Apisarnthanarak reported no relevant financial disclosures.

Conclusions

Disaster(s) will likely occur in your life time. Having a well preparedness plan before disaster is ideal, but perhaps impossible in several situations

Negotiating with hospital administration is the first step to allow time to create safety hospital environmental for the patients, but prepare to accept the all disappointments

Need to come up with key targets for implementation and consider local infrastructure and natural system to apply into the implementation plan

Solve the problem one by one and step by step with patient! Don't expect perfect outcomes

Be innovation and keep publishing because it can help others that may encounter the same disaster

Thank you very much for your attention!