

# Evaluation of Environmental Controls: Effectiveness and Cost

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# Goal of the presentation

- To overview engineering controls tested
- To describe the testing method used
- To present the testing results of some engineering controls available and an attempt of their cost effectiveness analysis

# Background

- High level of nosocomial transmission in TB facilities
- Unacceptable occupational TB incidence among staff
- Both increased availability and lack of resources for the infection control programs in TB facilities
- Increasing and diversifying commercialization of room air-cleaning devices
- Lack of independent reliable information about efficacy of available environmental controls

# Ventilation

Vladimir Oblast TB dispensary,  
“Alternativa – Klimat Ltd”, Vladimir

- General ventilation with heating of air, negative pressure wards, UVGI units for air decontamination from high risk zones
- Reconstruction 2005 – 2007
- Capital cost – 345000 USD
- Maintenance cost – 4425 USD per year
- Power consumption – 37 KW/h (electricity) and 0,8 GCal/h (heat)
- Service capacity – 17053 m<sup>3</sup> of building space



# Shielded UVGI fixture

(Modified OBN-150, P. Jensen, "Realnost Ltd" Vladimir

- 2 UVGI lamps Philips TUV-30W, one is shielded
- UVGI level for shielded lamp complies to Russian and international regulations:
  - In occupied area – less than  $0,2 \mu\text{W}/\text{cm}^2$
  - In upper room unoccupied area – higher than  $150 \mu\text{W}/\text{cm}^2$  at the distance of 1 m
- Cost - 200 USD
- Power consumption – 60 W



# Potok 150M-01

(«Potok-Inter», Moscow)

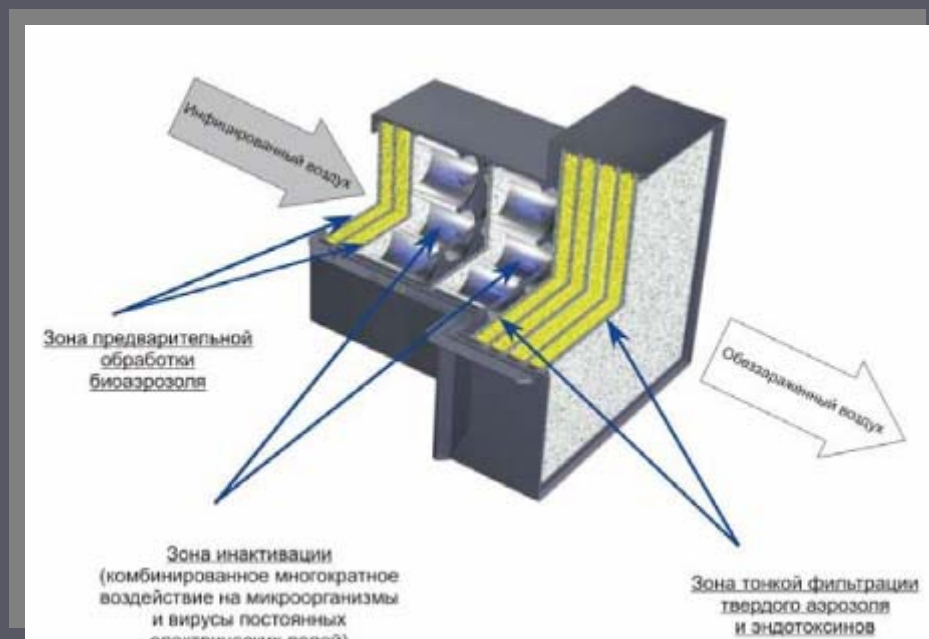
- Capacity – до 150 m<sup>3</sup>/h
- Power consumption - 40 W
- Weight - 9 Kg
- Dimensions - 420x322x360 mm
- Cost - 4800 USD



Function principle:

1 stage in inactivation zone – intensively fluctuating electric field and ions

2 stage in filtration zone – electrostatic catching of particles

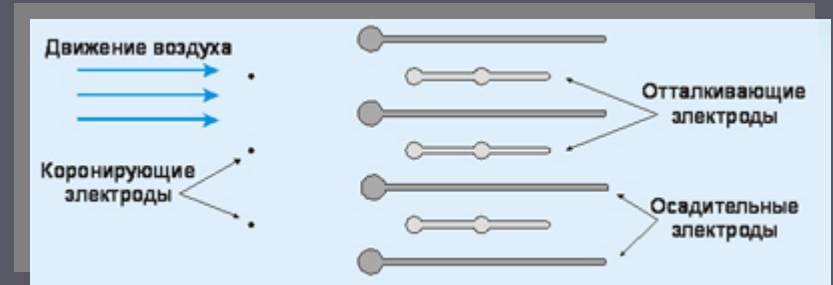


# Tree («EOL Ltd», Korolev)

## Tree – 100 ('single module'):

- Capacity:  $100 \pm 10$  m<sup>3</sup>/h;
- Dimensions: 430x300x150 mm;
- Power consumption - 40 W.
- Cost - 450 USD

Electrostatic air cleaner based on germicidal action of intensive "ionic wind" and intense voltage electric field

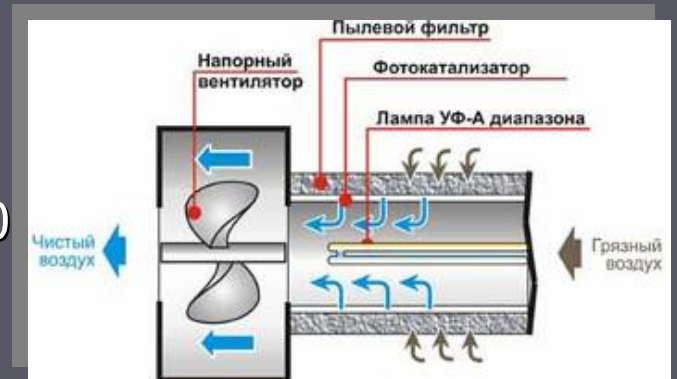


# Aerolife L (L - 9024 C)

«Aerolife Ltd», Lipetsk

- Power consumption - 29W
- Air flow capacity: night / daytime mode 65/90 m<sup>3</sup>/h
- UV lamp light wave length 320 – 400 nm.
- Dimensions 470 x 160 x 170 mm
- Weight 1.9 Kg
- Recommended room volume – no more than 90 m<sup>3</sup>
- Cost - 1270 USD

Air cleaner based on UV-induced photo-catalytic oxidation of air particles and gases on the photo-catalysator surface

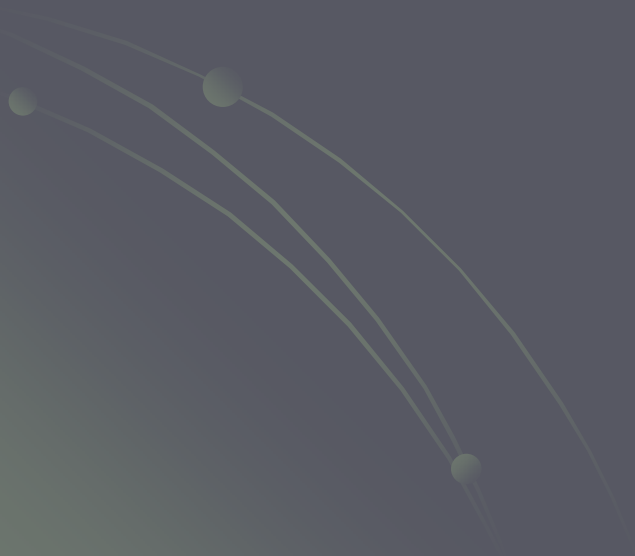


# Testing method

- Room:
  - Negative pressure patient ward  $S=11 \text{ m}^2 \times H=2,9 \text{ m}$  (Volume =  $32\text{m}^3$ )
- Equipment:
  - 1 compressor
  - 1 Collision nebulizer
  - 5 oil electric pumps
  - 4 Andersen One-Stage Viable (Microbial) Particle Sizing Samplers
  - 1 Andersen Six-Stage Viable (Microbial) Particle Sizing Sampler
  - Swinging mixing fan
  - Anemometer
  - Timer

# Testing method (2)

- Materials:
  - Sterile Petri dishes with nutrient soy agar
  - Suspensions of indicator microorganisms:
    - *Bacillus subtilis*
    - *Serratia marcescens*



# Testing method (3)

Design:

3 replicates of:

2 microorganisms

Ventilation ON OFF

UVGI ON OFF

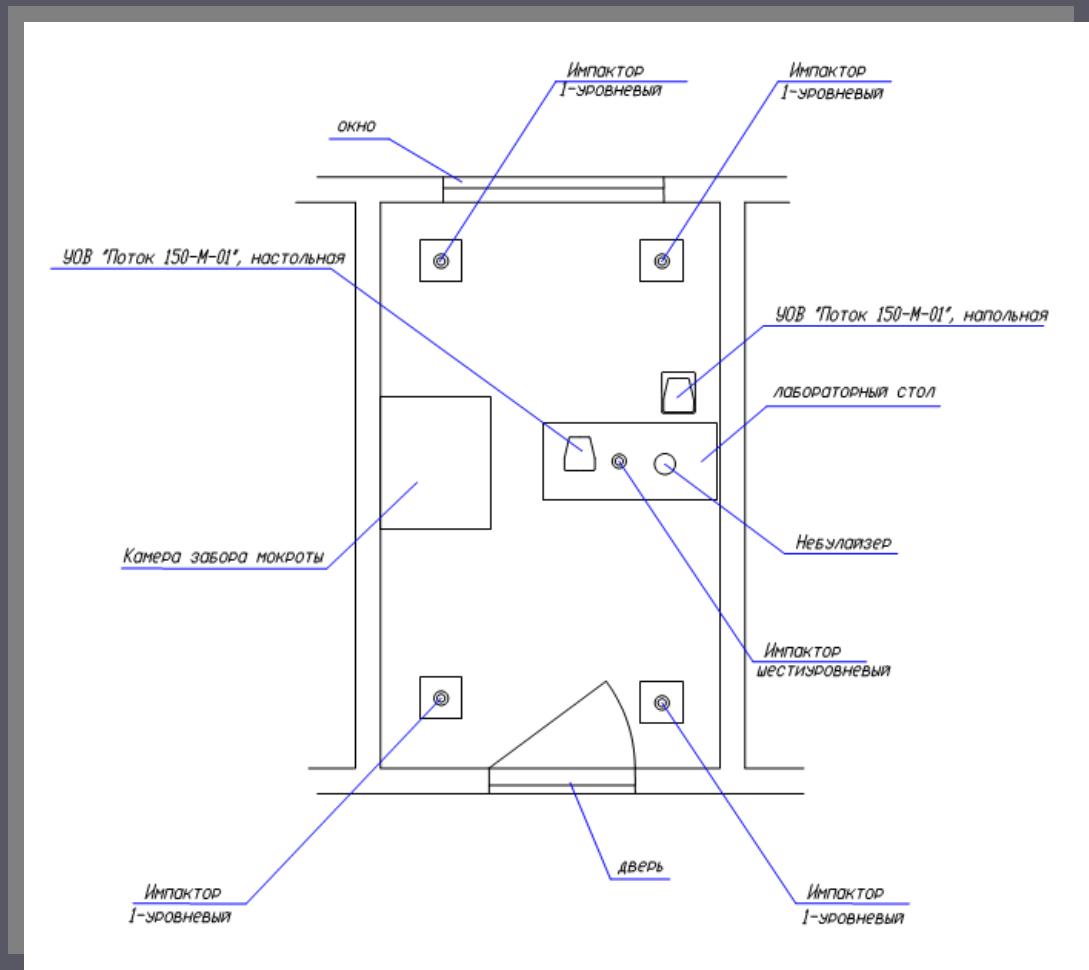
Potok ON OFF

Mixing Fan ON OFF

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Tree ON OFF

Total - 144 experiments,  
12960 air samplings



# Testing method (4)

- Protocol approved by P.Jensen (CDC), V.A. Puzanov (CTRI) and manufacturers

Дата	22-Jan-07	3 Условия теста	Вентиляци	On / Off
			ПОТОК	On / Off
Микроорганизм:	<i>Serratia marcescens</i>		УФ - лампа	On / Off
	<i>Bacillus subtilis</i>		Вентилятор	On / Off
<b>Вентиляционная решетка двери закрыта!!!</b>				
<b>Перед первым экспериментом каждого дня:</b>				
1. Включить все насосы, убедиться, что ВСЕ работают, отключить				
2. Включить ПОТОК, убедиться, убедиться, что горит ЗЕЛЕНый индикатор около кнопки 1 , отключить ПОТОК.				
3. Убедиться, что общая вентиляция отключена				
4. Убедиться, что УФ лампа отключена				
5. Проверить и отрегулировать КРАСНый компрессор - 20 PSI или 1 BAR				
6. Если будет включена вентиляция, проверить скорость потока - $2,35 \pm 0,11$ м/сек на B5-N9				
7. На каждом цилиндре Андерсена проверить скорость потока - $0,93 \pm 0,04$ м/сек				
Разведение в	__100__ mL суспензии + __0__ mL физраствора = 100 mL раствора для небулайзера			

# Testina method (5)

Время дня	Время	Время от начала теста (мин)	Время отбора (мин)	Объем отбора (L)	Номер чашки	Результат чтения чашки
12:17	t <sub>0</sub>	0				
12:37	t <sub>1</sub>	20	4	113	1511	180
	t <sub>1</sub>	20	4	113	1512	154
	t <sub>1</sub>	20	4	113	1513	244
	t <sub>1</sub>	20	4	113	1514	384
	t <sub>1</sub>	20	4	113	1515	400
	t <sub>1</sub>	20	4	113	1516	400
	t <sub>1</sub>	20	4	113	1517	399
	t <sub>1</sub>	20	4	113	1518	400
	t <sub>1</sub>	20	4	113	1519	400
	t <sub>1</sub>	20	4	113	1520	400
12:47	t <sub>2</sub>	30	4	113	1521	334
	t <sub>2</sub>	30	4	113	1522	328
	t <sub>2</sub>	30	4	113	1523	319
	t <sub>2</sub>	30	4	113	1524	114
12:57	t <sub>3</sub>	40	4	113	1525	20
	t <sub>3</sub>	40	4	113	1526	н/д
	t <sub>3</sub>	40	4	113	1527	18
	t <sub>3</sub>	40	4	113	1528	28
13:07	t <sub>4</sub>	50	4	113	1529	7
	t <sub>4</sub>	50	4	113	1530	10
	t <sub>4</sub>	50	4	113	1531	6
	t <sub>4</sub>	50	4	113	1532	3
13:17	t <sub>5</sub>	60	10	283	1533	7
	t <sub>5</sub>	60	10	283	1534	8
	t <sub>5</sub>	60	10	283	1535	8
	t <sub>5</sub>	60	10	283	1536	8
13:47	t <sub>6</sub>	90	10	283	1537	10
	t <sub>6</sub>	90	10	283	1538	н/д

$$F = ke^{-ACHt}$$

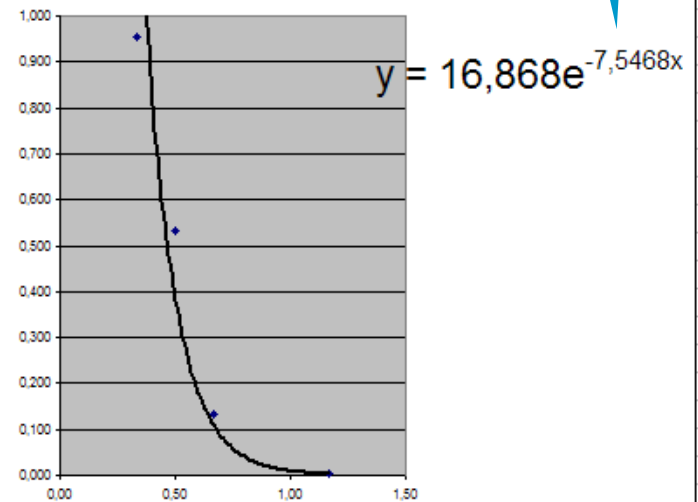
- F – remaining fraction of viable microorganism particles;
- $ACH$  – equivalent air changes per hour;
- t – elapsed time (hours)

# Testing method (6)

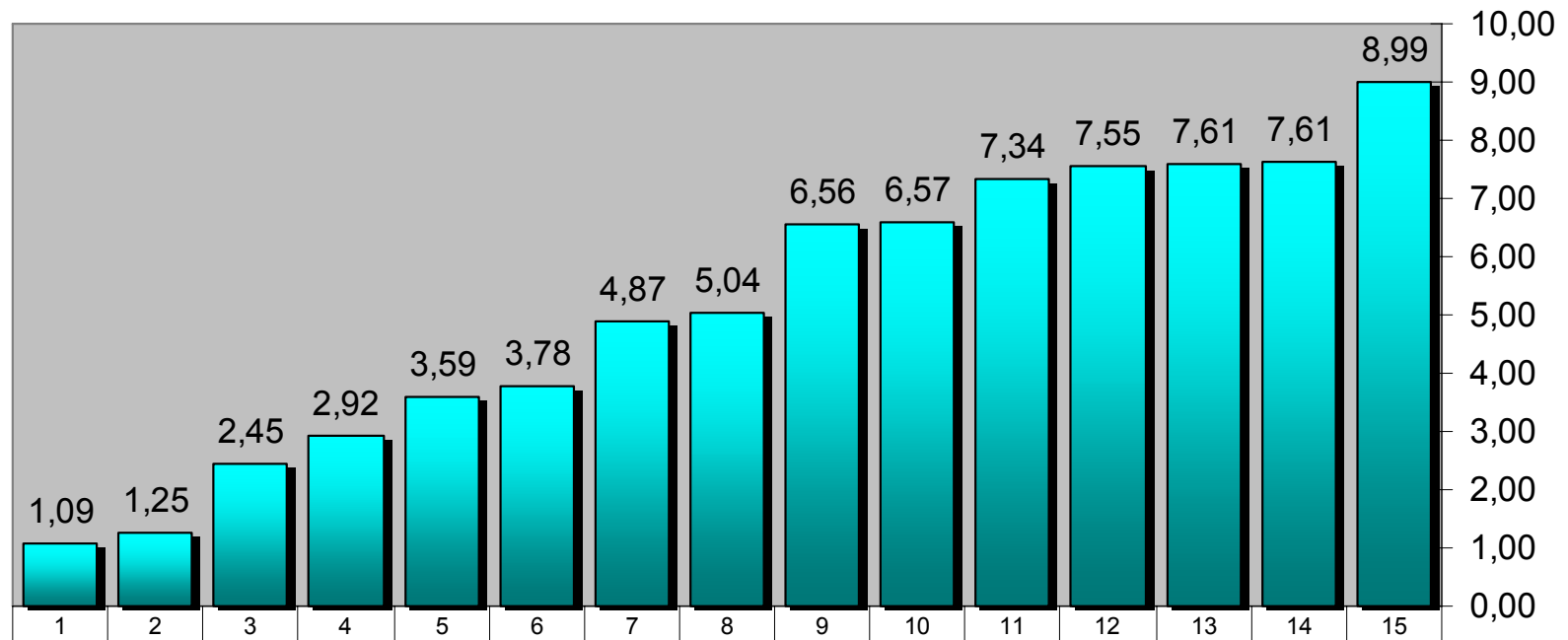
Разведение в небулайзере: 0,1 ml суспензии + 99,9 ml физраствора = 100 ml раствора для небулайзера							
Время дня	Время	Время от начала теста (мин)	Время отбора (мин)	Объем отбора (L)	Номер чашки	Результат чтения чашки	Примечания
12:34	t <sub>0</sub>	0					вентиляция ОТКЛ, Вентилятор ВКЛ, Небулайзер 20 PSI (1.4 Вд)
12:54	t <sub>1</sub>	20	4	113	1871	43	Небулайзер ОТКЛ, Установить условия теста!!!
	t <sub>1</sub>	20	4	113	1872	38	
	t <sub>1</sub>	20	4	113	1873	49	
	t <sub>1</sub>	20	4	113	1874	264	
	t <sub>1</sub>	20	4	113	1875	398	
	t <sub>1</sub>	20	4	113	1876	399	
	t <sub>1</sub>	20	4	113	1877	400	
	t <sub>1</sub>	20	4	113	1878	400	
	t <sub>1</sub>	20	4	113	1879	400	
	t <sub>1</sub>	20	4	113	1880	400	
13:04	t <sub>2</sub>	30	4	113	1881	400	
	t <sub>2</sub>	30	4	113	1882	398	
	t <sub>2</sub>	30	4	113	1883	397	
	t <sub>2</sub>	30	4	113	1884	399	
13:14	t <sub>3</sub>	40	4	113	1885	387	
	t <sub>3</sub>	40	4	113	1886	388	
	t <sub>3</sub>	40	4	113	1887	365	
	t <sub>3</sub>	40	4	113	1888	385	
13:24	t <sub>4</sub>	50	4	113	1889	231	
	t <sub>4</sub>	50	4	113	1890	209	
	t <sub>4</sub>	50	4	113	1891	211	
	t <sub>4</sub>	50	4	113	1892	199	
13:34	t <sub>5</sub>	60	10	283	1893	107	
	t <sub>5</sub>	60	10	283	1894	195	
	t <sub>5</sub>	60	10	283	1895	121	Hours
	t <sub>5</sub>	60	10	283	1896	119	0,00
	t <sub>5</sub>	60	10	283	1897	119	400
	t <sub>5</sub>	60	10	283	1898	119	1,000
14:04	t <sub>6</sub>	90	10	283	1897	2	0,17
	t <sub>6</sub>	90	10	283	1898	3	398
	t <sub>6</sub>	90	10	283	1899	3	0,953
	t <sub>6</sub>	90	10	283	1900	3	0,530

Air Changes per Hour

Ventilation + UV:  
B. subtilis

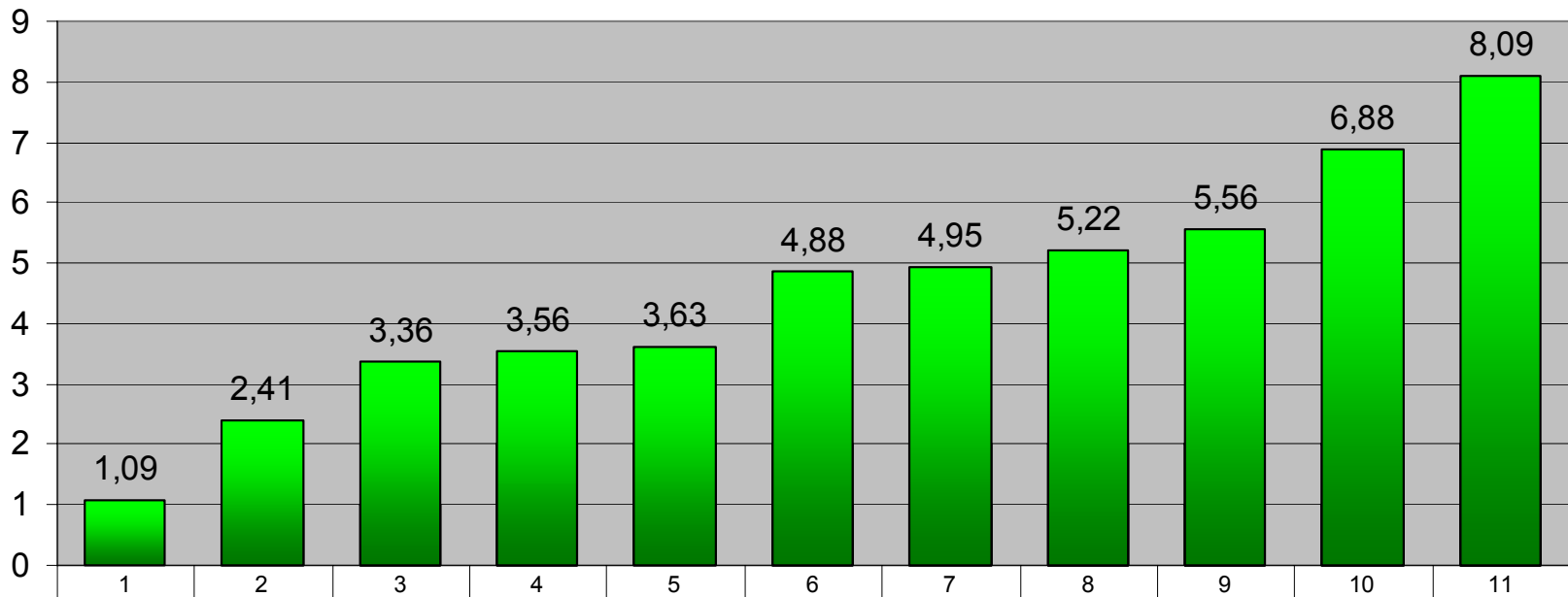


## POTOK Air Cleaner Testing Results (ACH equivalent, B. subtilis)



Ventilation			1	1			1	1		1		1			1
POTOK					1	1	1	1		1	1			1	1
UVGI									1	1	1	1	1	1	1
Mixing fan	1			1		1		1					1	1	1
Mean ACH	1,09	1,25	2,45	2,92	3,59	3,78	4,87	5,04	6,56	6,57	7,34	7,55	7,61	7,61	8,99

## TREE Air Cleaner Testing Results (ACH equivalent, B. subtilis)



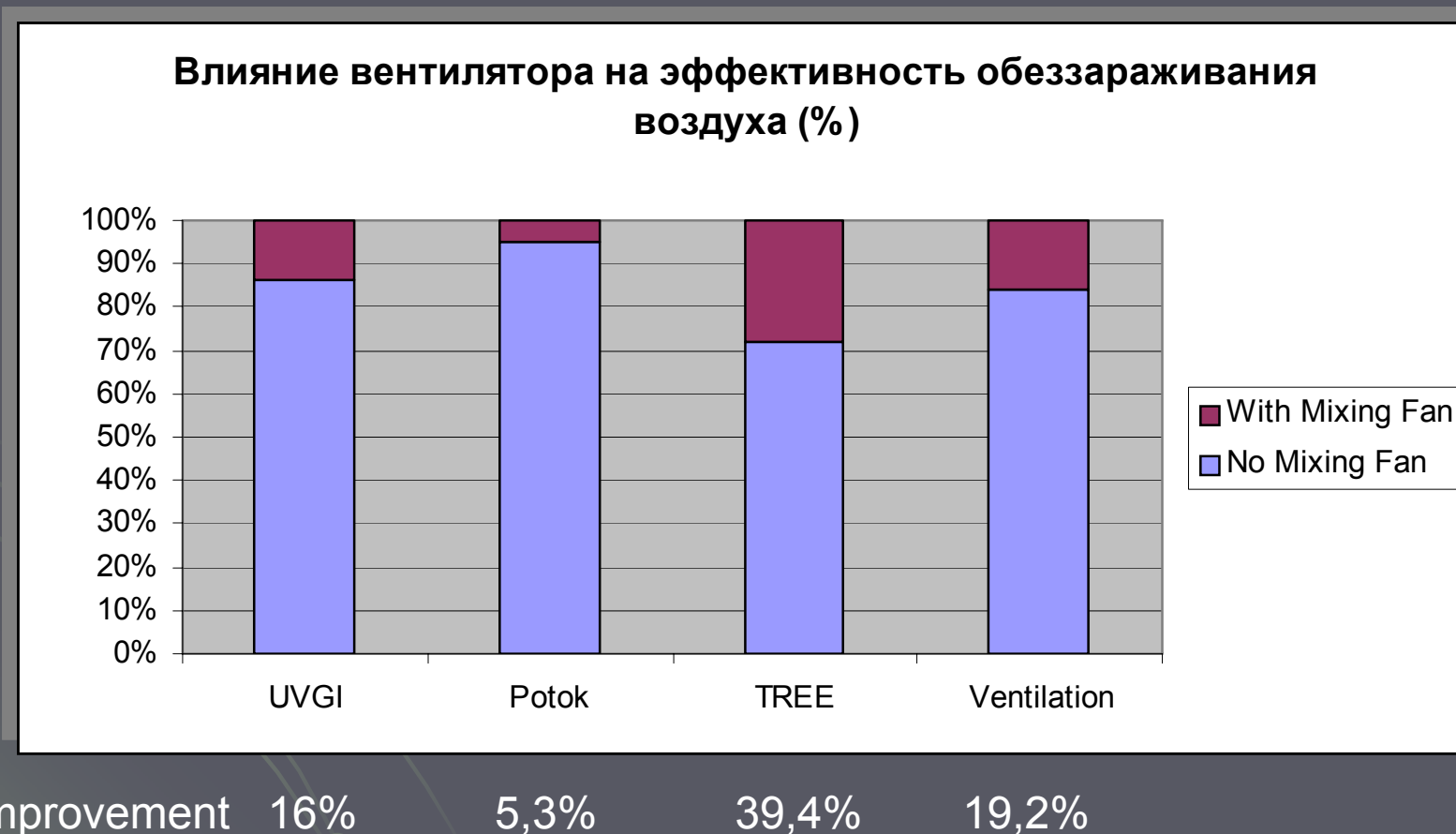
	1	2	3	4	5	6	7	8	9	10	11
Ventilation						1		1		1	1
TREE		1	1	2	2	2	2	2	2	2	2
UVGI							1		1	1	1
Mixing fan			1	2				2	2		2
Mean ACH	1,09	2,41	3,36	3,56	3,63	4,88	4,95	5,22	5,56	6,88	8,09

# Actual Detected Efficacy

(equivalent Air Changes per Hour, ACH)

	Ventilation	Shielded UVGI fixture	Potok 150M-01	Tree -100	Aerolife-L
Capacity according to official manufacturer documentation	7,5	-	4,68	3,13	2,81
Actual capacity by testing results	2,45	6,56	3,59	3,63	2,20

# Importance of good air mixing (impact of mixing fan)

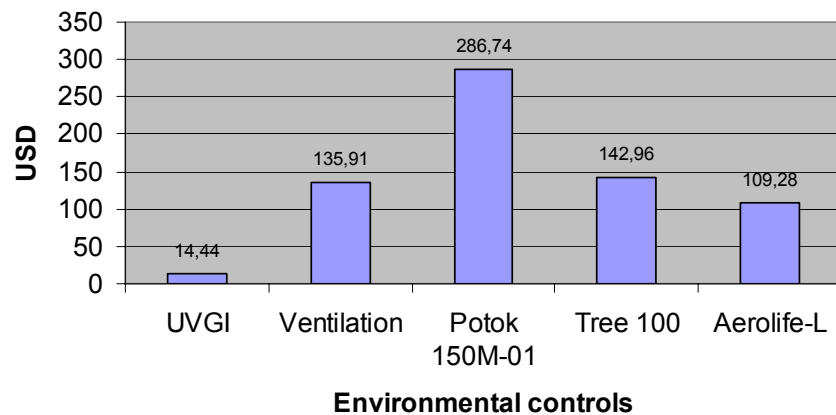


# Relative cost of each evaluated environmental control (USD/ACH)

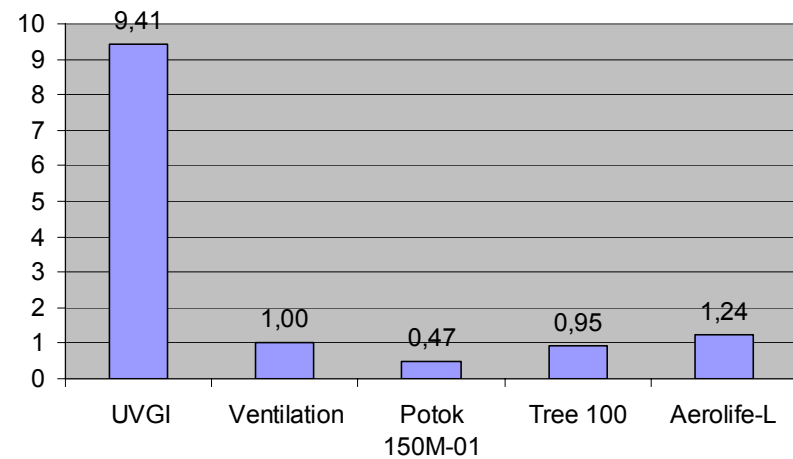
Engineering controls	Capital and installation cost	Maintenance cost per month	Cost of materials per month	Cost of supplies per year	Unit life	Electrical energy consumption (W)	Heat energy consumption (Kcal/h)	Relative Capacity (patient wards S 32m3)	Determined Efficacy (ACH)	Cost of using (USD per year)	Relative cost (USD / equivalent 1 ACH during 1 year in one 32 m3 patient ward)
UVGI	200	0,5	0,3	15	10	60	0	1	6,56	94,69	14,44
Ventilation	345000	369	22,5	0	10	37000	800000	533	2,45	177475,25	135,91
Potok 150M-01	4800	2	1	0	5	40	0	1	3,59	1029,40	286,74
Tree 100	450	25	6	34,6	5,7	40	0	1	3,63	518,94	142,96
Aerolife-L	1270	3	3	17,2	10	29	0	1	2,20	240,41	109,28

# Cost effectiveness of tested controls

**Cost of 1 equivalent ACH in the patient room**



**Relative economical efficiency (Ventilation = 1,0)**



# Conclusions

- Actual capacity of various engineering controls in the particular hospital settings can differ remarkably from the officially declared by manufacturer data
- Independent adequate testing method of their efficacy is needed
- Combined use of different controls does not assume the simple sum of their efficacy
- Mixing fan and appropriate installment can substantially improve the performance of engineering controls
- Shielded UVGI fixtures remain the most effective and the least costly engineering control for TB facilities

Thanks to Paul A. Jensen, CDC  
for idea, expert and technical  
support of this research



Questions?