Rigshospitalet

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TEST OF THE NOVAERUS AIR CLEANING SYSTEM IN THE DEPARTMENT OF CLINICAL MEDICINE.

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NOVAERUS AIR CLEANING SYSTEM.

The Novaerus air cleaning system is based on the plasma disinfection technique. An aggregate of ionising air molecules to reactive radicals is inserted into the device and has a strong antimicrobial effect. These reactive radicals also affect other molecules such as allergens and aroma molecules.

Air is actively sucked into the device and through the plasma aggregate, where micro-organisms are killed and other molecules are modified. Dust particles can be so large that when passing the plasma aggregate, the amount of reactive radicals are so numerous that light flashes are emitted.

As the device does not emit radiation or chemical compounds it can be used in an in-patient department while patients are staying in the room.

Design of project.

Two identical departments (3131 and 3132) in the Nephrology Clinic were chosen for the investigation.

Interventions were performed in one of the departments (3132) where the Novaerus device was installed. In one half of the control departments, 2 devices were installed in each room (called 3132-2) and in the other half, one device was installed in each room (called 3132-1). Furthermore, 6 large devices were installed in the hall area. However these were dismantled during the investigation due to light flashes, probably due to existing dust particles. The specific rooms included in the investigation can be seen in the tables included in the report.

In the other department (3131), no Novaerus devices were installed and it served as the control (called 3131-0). The specific rooms included in the investigation can be seen in the tables included in the report.

Sample times.

Microbiology samples were taken prior to the installation of the Novaerus devices (1st measurement taken on 3rd-4th Mar 2014). Then the devices were installed without being turned on for 14 days. Subsequently the devices were turned on and after having been on for 21 days samples were taken (2nd measurement 9th Apr 2014).

Then the devices were turned off once again for 21 days with a new subsequent sampling (3rd measurement 30th Apr 2014). The Novaerus devices were turned on again and after 3 months additional samples were taken (4th measurement 2nd Sep 2014). To investigate the

long-term effect of the Novaerus devices they remained turned on for a further 2 1/2 months with new subsequent sampling (5th measurement 17th Nov 2014).

Samples.

Microbiology samples were taken and samples for allergens and aroma compounds were not.

Samples for bacteria and fungus were taken during each measurement. At the 3rd and 5th measurement there were also samples taken for respiratory tract viruses.

An air sample in four rooms in each of the 3 units (3131-0, 3132-1, and 3132-2) was attempted, along with an air sample in each of the 2 halls. The samples were taken with an air sampler assimilating 1 m^3 of air and depositing bacteria and fungus on a plate with tryptic soy agar (TSA), which was incubated at 37°C for 48 hours, and the number of colonies was read.

Samples from impressions from windowsills and cabinets in 4 rooms in each of the 3 units (3131-0, 3132-1 and 3132-2) were taken with tryptic soy agar (TSA) impression plates. These measurements are regarded as being representative of what falls out of the air, but they can also include human touch.

Samples in serum bouillon from beds and floors in 4 rooms in each of the 3 units (3131-0, 3132-1 and 3132-2) were taken. The samples were taken from patient beds and in the offices from chairs and floors. The samples were grown for 24 hours and inoculated with the aim to verify small quantities of potentially pathogenic bacteria.

3 inoculations were taken with large inoculation swabs from 3 places in the intervention units (3132-1 and 3132-2) and from 4 places in the control unit (3131-0). The swabs were placed in a virus transport medium inhibiting bacteria growth. The samples were analysed for a panel of respiratory tract viruses including e.g. influenza virus, parainfluenza virus, rhinovirus, coronavirus etc.

Results.

There is a relatively large variation in the air measurements, both from hall to hall and within the individual sample days (Figure 1a). It looks as if it is to a larger extent a measure of the current activity in the department rather than an effect of the Novaerus devices.

Germ count in the air, cultured at 37ºC:

Unit	Room	1st measurement	2nd measurement	3rd measurement	4th measurement	5th measurement
3132-1	13367-Office	67 (62 CNS)	167	52	392	104
	13363	124 (123 CNS)	442	44	Withdrawn	Withdrawn
	13359	84 (68 CNS)	190	43	223	132
	13355-Office	76 (74 CNS)	89	33	366	134
	13353-Hall	117 (110 CNS)	133	55	291	124
3132-2	13391	69 (53 CNS)	196	94	237	69
	13387	54 (43 CNS)	160	50	263	118
	13383	51 (48 CNS)	99	67	453	167
	13379	53 (50 CNS)	199	97	320	93
3131	13340-I	117 (117 CNS)	186	82	131	Withdrawn
	13336	137 (134 CNS)	124 (excessive growth)	71	89	94
	13332	98 (91 CNS)	255 (excessive growth)	114	194	Withdrawn
	13322	264	103	50	Withdrawn	89

		(248 CNS)	(excessive growth)			
	13306 -Hall	186 (184 CNS)	110 (excessive growth)	49	344	124

When investigating the average values of the air measurements in the three areas with two, one and zero devices, there is no significant difference in the three areas (Figure 1b).

Figure 1a.

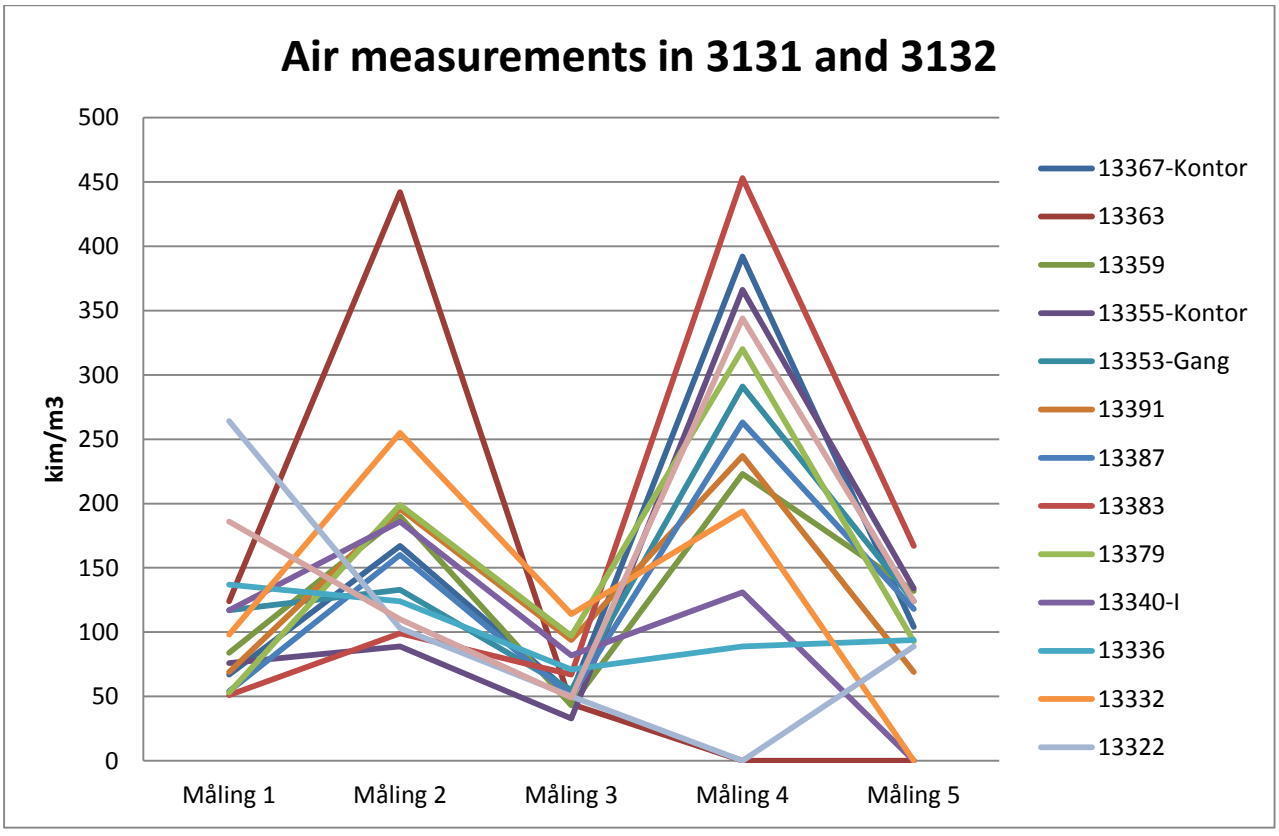
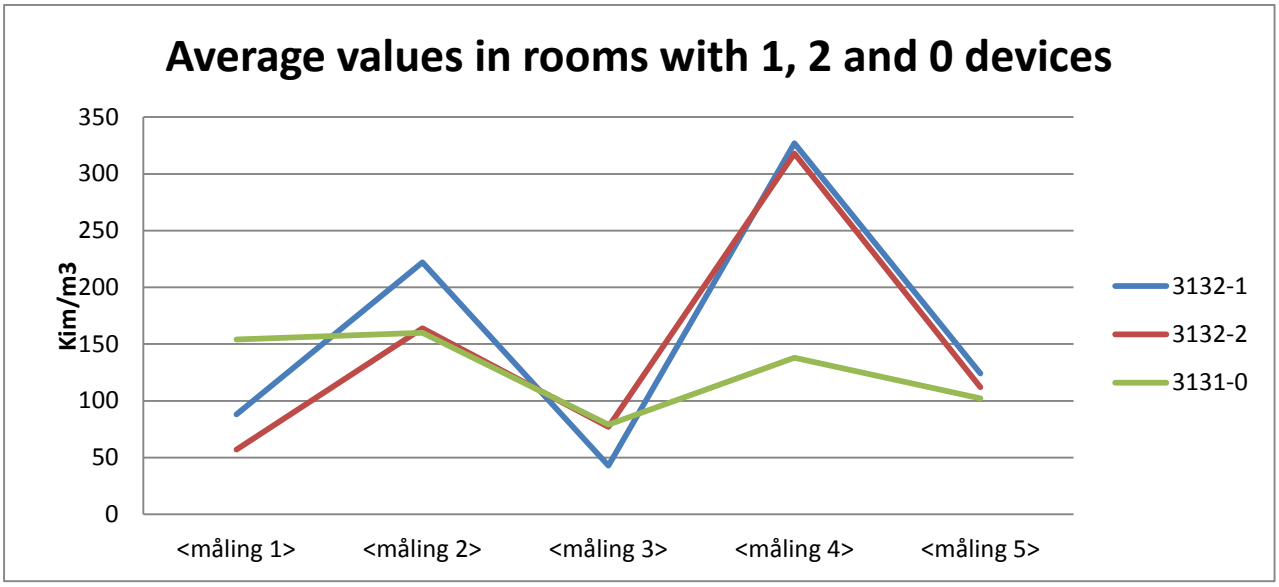


Figure 1b.



Tryptic Soy Agar (TSA) impression plates from the windowsills had on average a lower germ count than the air measurements. They were completely dominated by the normal flora of skin, coagulase negative staphylococci (CNS) (Table 1).

Table 1. ***TSA impressions, windowsill***:

Unit	Room	1st measurement	2nd measurement	3rd measurement	4th measurement	5th measurement
3132-1	13367-K	37 (34 CNS)	4	19	25	40
	13363	34 (34 CNS)	25	62	Withdrawn	Withdrawn
	13359	71 (3 CNS)	12	22	18	8
	13355-K	8 (7 CNS)	3	28	14	36
	13353-G	Withdrawn	Withdrawn	Withdrawn	Withdrawn	Withdrawn
3132-2	13391	24 (24 CNS)	2	6	33	39
	13387	14 (14 CNS)	35	17	23	30
	13383	14 (9 CNS)	41	6	11	18

	13379	4 (4 CNS)	24	32	7	67
3131	13340 -I	11 (11 CNS)	36	69	39	Withdrawn
	13336	37 (34 CNS)	7	134	60	68
	13332	10 (10 CNS)	20	123	5	Withdrawn
	13322	16 (16 CNS)	5	60	Withdrawn	Withdrawn
	13306 -G	Withdrawn	Withdrawn	Withdrawn	Withdrawn	Withdrawn

Figure 2a shows that there is a large variation in the measurements, both from one day of sampling to the next and within the individual sample days. It is of more interest that the values in rooms with Novaerus devices are lower than in rooms without them (Figure 2b). This may be caused by fewer bacteria falling out of the air over a longer period, which is not reflected by the air measurements which are snapshot measurements.

Figure 2a.

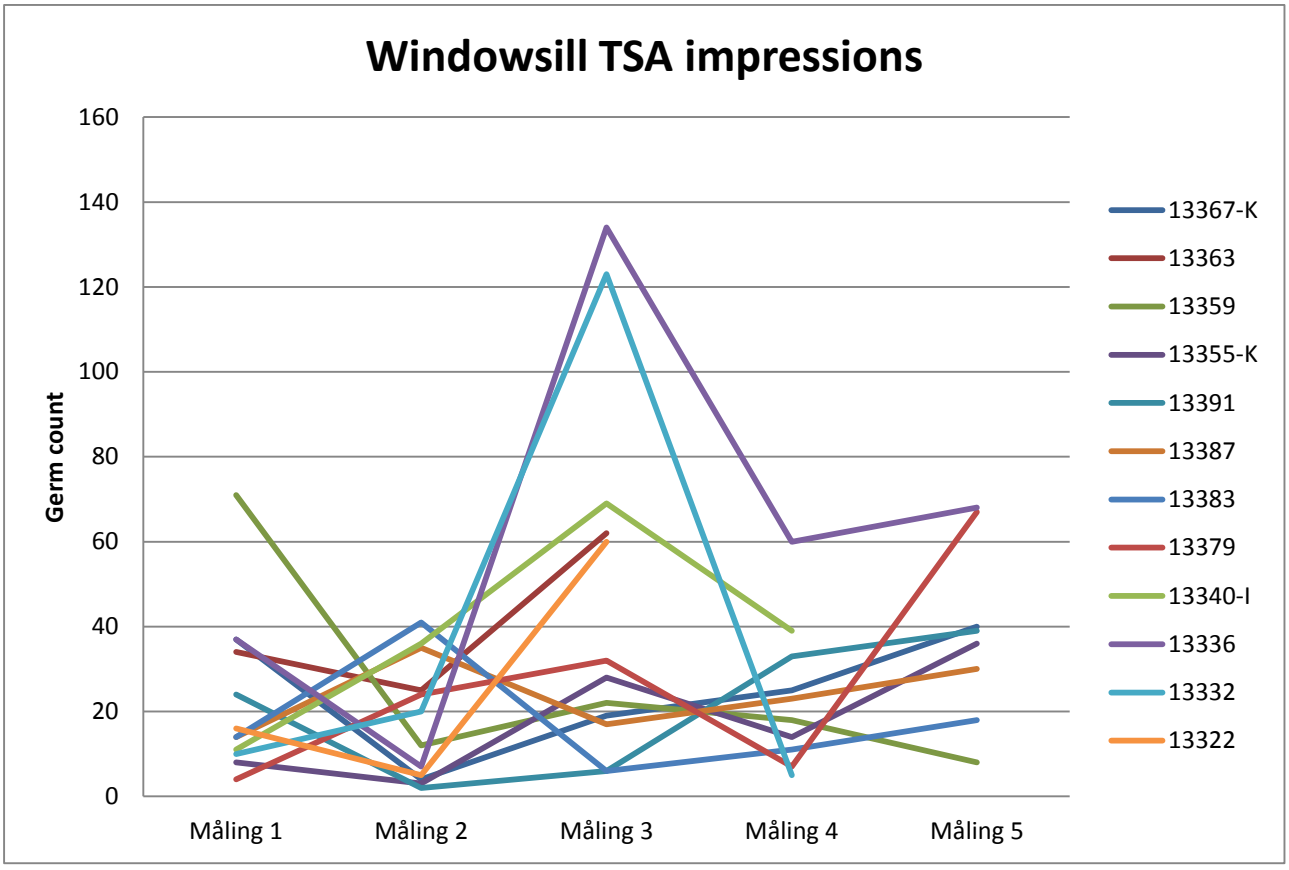
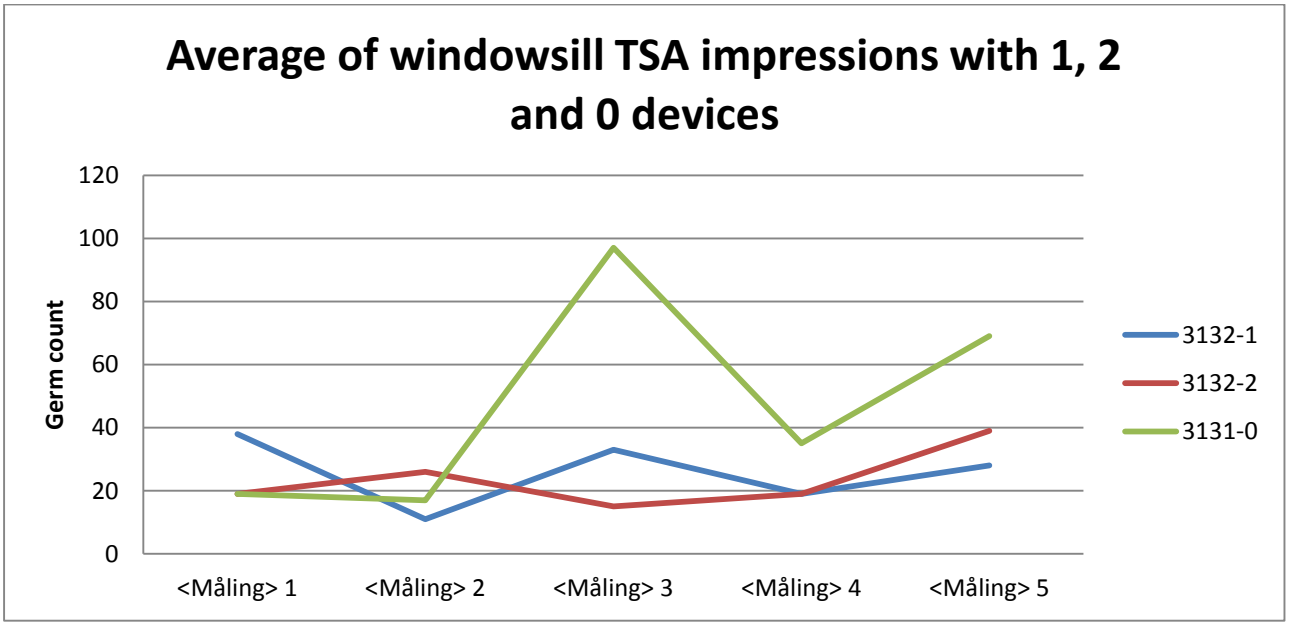

Windowsill TSA impressions
160
140
120
100
80
60
40
20
0
Germ count
Måling 1
Måling 2
Måling 3
Måling 4
Måling 5
13367-K
13363
13359
13355-K
13391
13387
13383
13379
13340-I
13336
13332
13322

Figure 2b.


Average of windowsill TSA impressions with 1, 2 and 0 devices
120
100
80
60
40
20
0
Germ count
<Måling> 1
<Måling> 2
<Måling> 3
<Måling> 4
<Måling> 5
3132-1
3132-2
3131-0

As for the Tryptic Soy Agar (TSA) impression plates, the impression plates from the tops of the cabinets also had a consistently lower germ count than the air measurements. Aside from being dominated by normal flora of skin coagulase negative staphylococci (CNS), many *Bacillus* species were also found in these samples (Table 2).

Table 2. *TSA impression, cabinet*:

Unit	Room	1st measurement	2nd measurement	3rd measurement	4th measurement	5th measurement
3132-1	13367-K	15 (11 CNS)	28	12	18	52
	13363	57 (51 CNS)	124	53	Withdrawn	Withdrawn
	13359	21 (2 CNS)	68	22	20	87
	13355-K	16 (14 CNS)	44	28	10	36
	13353-G	Withdrawn	Withdrawn	Withdrawn	Withdrawn	Withdrawn
3132-2	13391	75 (62 CNS)	99	40	9	57
	13387	43 (41 CNS)	70	63	42	30
	13383	114 Excessive growth	20	32	13	18
	13379	79 (68 CNS)	26	68	10	67
3131	13340-I	64 (58 CNS)	128	82	45	Withdrawn
	13336	86 (78 CNS)	66	71	80	3
	13332	19 (9 CNS)	37	94	51	Withdrawn
	13322	10 (2 CNS)	159	135	Withdrawn	37
	13306-G	Withdrawn	Withdrawn	Withdrawn	Withdrawn	Withdrawn

Figure 3a shows that there is a large variation in the measurements, both from one day of sampling to the next and within the individual sample days. It is of more interest that the values in rooms with Novaerus devices are lower than in rooms without devices (Figure 3b). In this case, this may also be caused by fewer bacteria falling out of the air over a

longer period, which is not reflected by the air measurements. However, this does not explain why the values are higher with one than with two devices.

Figure 3a.

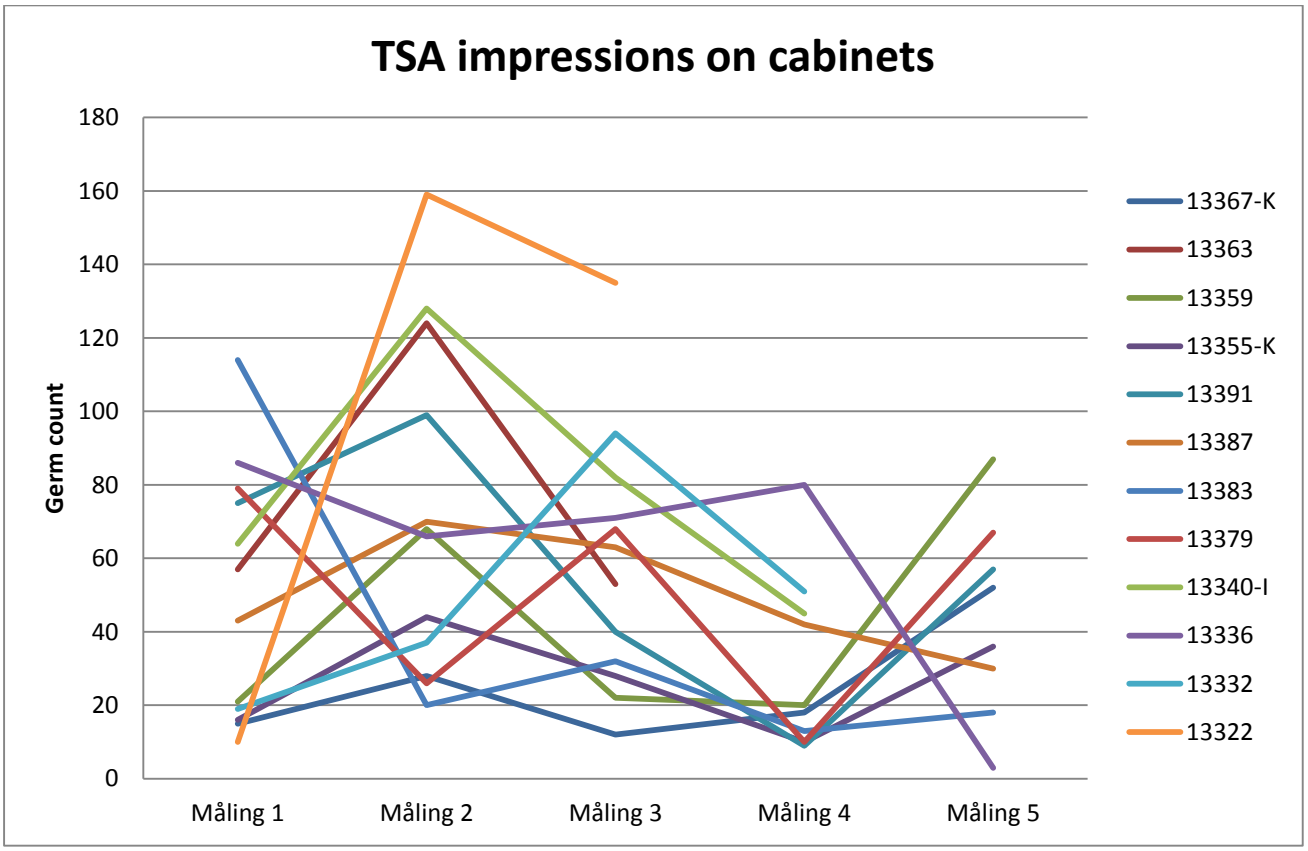
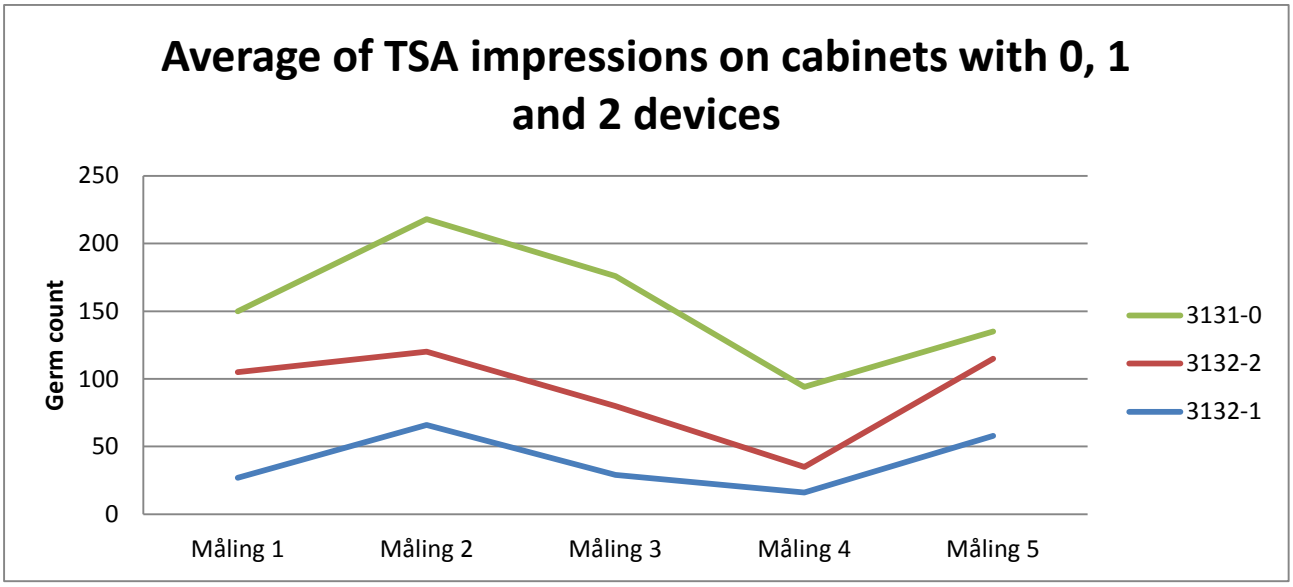


Figure 3b.



Growth of incubations in serum bouillon was carried out in order to find possible potentially pathogenic bacteria in the environment, as it is a more sensitive method than the TSA impression plates. Potentially pathogenic bacteria were identified with MALDI-TOF.

The samples were taken from patient beds and from chairs in offices (Table 3). Also growth samples were taken from the floors (Table 4).

In both tables, potentially pathogenic bacteria are marked in red.

CNS = coagulase negative staphylococci (normal flora of skin).

B.sp. = *Bacillus* species (often found in dust)

B.c. = Bacillis cereus (often found in dust).

A substantial part of the samples are withdrawn. No samples were taken on the first day of measurement. The other days without sampling were due to the fact that isolation patients were in the room thus preventing sampling.

There was potentially pathogenic bacteria in 4 of the samples from the area with one Novaerus device and in 9 samples where 2 devices were present in the room whereas there were only 6 samples with potentially pathogenic bacteria when no device was present (Table 3).

There was pathogenic bacteria in 5 of the samples from the floor in the area with one Novaerus device and in 3 samples with 2 devices in the room, whereas 6 samples with potentially pathogenic bacteria were identified where no device was installed (Table 4).

Both in samples from the beds and the floors, there was an increased number of samples with potentially pathogenic bacteria the further the investigation progressed. The devices do not have an effect of the number of potential pathogenic bacteria, and the results are probably more a reflection of staff conduct.

Table 3. ***Growth: Bed/chair.***

Unit	Room	1st measurement	2nd measurement	3rd measurement	4th measurement	5th measurement
3132-1	13367-K	Withdrawn	CNS B.sp. Ps. luteola	CNS	CNS B.sp. B.c.	B.c.
	13363	Withdrawn	B.sp. CNS	CNS B.sp. B.c.	Withdrawn	Withdrawn
	13359	Withdrawn	CNS	CNS E. faecalis	CNS B.c.	B.sp.
	13355-K	Withdrawn	B.sp.	CNS B.sp. Pantoea	B.c.	CNS E. faecium B.c.
	13353-G	Withdrawn	B.sp. CNS	CNS	CNS Pantoea	B.sp.
3132-2	13391	Withdrawn	CNS B.sp. E. faecium	B.sp. E. faecalis	CNS B.sp. B.c. Lactobacillus	CNS E. cloacae E. faecium B.c.
	13387	Withdrawn	E. coli	CNS B.sp.	CNS B.c.	CNS E. faecium B.c.
	13383	Withdrawn	CNS B.sp.	CNS	B.c. K. oxitoca	CNS B.c.
	13379	Withdrawn	B.sp.	B.c.	CNS	CNS

			CNS K. pneumo	E. faecalis	B.c. E. faecium	E. faecium A. baumanni B.c.
3131	13340 -I	Withdrawn	B.c. CNS	CNS	B.c. S. aureus Enterobacter	Withdrawn
	13336	Withdrawn	CNS S. aureus	CNS	CNS B.c. E. faecium	CNS E. faecalis
	13332	Withdrawn	B.c. CNS	B.sp. E. cloacae	CNS B.c. E. faecalis	Withdrawn
	13322	Withdrawn	B.sp. CNS	CNS B.sp.	Withdrawn	CNS E. faecalis C. freundii B.c.
	13306 -G	Withdrawn	B.sp.	B.c. E. faecalis	CNS B.sp. B.c. E. faecium	CNS B.c.

Table 4. ***Growth, floor***:

Unit	Room	1st measurement	2nd measurement	3rd measurement	4th measurement	
3132 -1	13367 -K	Withdrawn	B.sp.	CNS B.sp.	CNS B.sp.	CNS B.sp.
	13363	Withdrawn	B.sp. CNS	B.sp. B.c. A. baumanni	Withdrawn	Withdrawn
	13359	Withdrawn	B.c.	CNS E. faecium	CNS B.c.	CNS
	13355 -K	Withdrawn	B.sp.	B.sp. B.c. E. faecium	B.sp. B.c.	CNS B.c.
	13353 -G	Withdrawn	B.sp. CNS	B.sp. B.c. E. faecalis	CNS B.c. Acinetobacter Streptococcus	E. faecalis B.c. B.sp.
3132 -2	13391	Withdrawn	B.c.	B.sp.	CNS B.sp. B.c.	CNS B.c.
	13387	Withdrawn	B.sp. CNS	B.sp. S. aureus E. faecalis	CNS B.sp.	CNS E. faecium B.sp.

	13383	Withdrawn	B.sp. CNS	B.sp. Ps.sp.	CNS B.c. Streptococcus	CNS Corynefor m B.c.
	13379	Withdrawn	B.sp. CNS	CNS	CNS B.sp.	CNS E. faecalis
3131	13340 -I	Withdrawn	B.c. CNS	CNS S. aureus	B.c. S. aureus	Withdrawn
	13336	Withdrawn	B.c. CNS	B.c. Coryne	CNS E. faecalis A. baumanni Leclercia	CNS E. faecalis
	13332	Withdrawn	B.c. CNS	CNS B.sp.	CNS B.c.	Withdrawn
	13322	Withdrawn	CNS	CNS B.sp.	Withdrawn	CNS E. faecalis C. freundii B.c.
	13306 -G	Withdrawn	CNS Pantoea sp.	B.sp.	CNS B.c.	CNS B.c.

Virus investigations.

3 virus samples were taken in rooms with 1 Novaerus device and 3 virus samples from rooms with 2 devices and 4 virus samples from rooms without devices at the 3rd measurement (21 days after the device was turned off after having been on for 14 days) and the 5th measurement (the devices have been turned on for 5 1/2 months).

No virus was found in any of the 20 samples analysed for several respiratory tract viruses. The control department 3131 can be regarded as the baseline for the virus load in a nephrology unit. As no positive virus samples were found here, it would not be expected to find any virus in the control department 3132.

Effects on findings of bacteria in patients.

Positive microbiological samples from May to October 2013 (the year prior to the Novaerus investigation) were compared with positive microbiology samples from May to October 2014 (while the Novaerus investigation was carried out).

Samples from surface localities, airways (expectorates), incubations from incisions sites, other incubations and urine were chosen as indicators. In Table 5 the number of patients with positive microbiological samples is stated.

In the control department 3131, the number of patients with positive microbiology indicator bacteria increased by 35% from 2013 to 2014, whereas the number of patients with positive microbiological indicator bacteria reduced by 23% in the department with intervention 3132. That sums up to a difference of more than 50% in the two departments.

It has not been taken into consideration whether more or less samples were taken in the two departments during the two periods. The difference is so large that this alone cannot most likely explain the resulting difference. The findings of bacteria in the urine samples especially constitute the difference between the control department and the department with intervention.

Table 5.

Sample types	**3131**		**3132**	
	2013	**2014**	**2013**	**2014**
Expectorates	4	8	13	14
Incubations, incision site	2	1	4	2
Other incubations	8	4	13	14
Urine	20	33	49	31
Total	34	46	79	61
Difference	+ 35%		- 23%	

Conclusion.

The effect of the Novaerus devices cannot be measured as a snapshot of the current bacterial load in the air with air samples. However it looks as if there is a certain reduction in the bacterial load which had fallen onto surfaces such as windowsills and on top of cabinets. The latter are surfaces which are not touched too frequently and where the occurrence of bacteria is primarily due to fallout from the air rather than from human touch. The reduction in bacterial load is however approximately the same in windowsills and on cabinets. However, it doesn't appear as if there is any difference in using one or two Novaerus devices in the rooms.

As there is no virus in the control department or in the department with intervention the effect of Novaerus devices on viruses has not been clarified in this investigation. This will require a new study focusing on viruses in departments where the occurrence has been clarified prior to the start of the investigation.

When the number of patients with positive microbiology samples from surface localities is examined, a reduction of about 50% is seen in the department with intervention, where the Novaerus devices have been installed, compared to the control department. This

difference is caused by urine samples containing bacteria. Why the difference is only observed in urine samples and not in other superficial samples may be a coincidence just as it has not been taken into account whether there were a larger or smaller number of samples in the investigated periods.

The results show that the Novaerus device may be effective with both airborne bacteria which had fallen onto surfaces and on the occurrence of positive microbiological samples. It would be interesting to continue the investigation, especially with regard to the effect on viruses and additionally the effect on airway symptoms in patients and staff.