COMPARISON OF FAN ALTERNATIVES FOR OPTIMIZED AIR PURIFICATION

HAMK
HÄMEEN AMMATTIKORKEAKOULU
HÄME UNIVERSITY OF APPLIED SCIENCES

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Silvia-Ruxandra Lupea

ABSTRACT

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Author Silvia-Ruxandra Lupea **Year** 2018

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Supervisor(s) Katariina Penttilä

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After all the testing was concluded, the analysing stage began. During this stage, the results from the tested fans were compared to the results from the original fan used by the purification machine. The conclusion of this project was that there is no suitable replacement to be found among the fans tested here. It is recommended that, as the fan technology is advancing a new test may prove to give more fruitful results in the near future.

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Keywords purification, fan, air flow, differential pressure

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1 INTRODUCTION

This project is comprised of a comparison of different fans in order to find a suitable replacement to an air purification system. The project work is conducted in three different stages: the empirical stage, the test stage and the analysis stage. At the research stage the author researched and identified fitting substitutes for a fan in an air purification system. In the test stage the author assessed their true capacity. And in the analysis stage the author evaluated the results and delivered the conclusion of which product is the best suited to the commissioning party.

1.1 Description of Tasks

The tasks were, as noted previously, separated into three stages.

At the first stage, the empirical stage, the author explored the different fan options available in the local market from two local distributors. Based on a set standard (high air flow rate, low differential pressure, etc.) chose a number of fans to be studied and fitted into the commercial purification machine.

Next, after the selected fans arrived at the testing site, cane the test stage. In this stage the fans were, one at a time, mounted in the air purification appliance. The machine was turned on and the air flow rate was matched to be identical to the original fan and measured. After this, the sound levels were measured in a decently soundproofed room. All the data was collected in order to be used in the next phase of the study.
Lastly, the analysis stage, consists of comparing the data gathered from the new fans to the data obtained from the fan currently used and drawing up a conclusion.

Ideally, in the European market area there are suitable replacements which can generate more efficient air purification, and thus more profit.

1.2 General Air Purification Description

Air purifiers, known also as air cleaners, are devices which extract pollutants from the air in a room/building. (Purifier, 2018).

One might wonder what breathable air is, what it is made of. Well, in a nutshell, air is composed of five gases: Nitrogen (N_2), Oxygen (O_2), water vapour, Argon (Ar) and Carbon Dioxide (CO_2). From these five gases, Ni makes up approximately 78% of the atmosphere, O_2 makes up approximately 20%, and there other three gases making up less than one percent (1%). Besides these first major gases, there are also different small quantities, less than 1% of Neon (Ne), Methane (CH_4), Helium (He), Hydrogen (H_2) to name a few. (Lide, 1997).

Inhalable particles smaller than ten micrometres (µm) in diameter are a common type of air pollutants. A study has noticed the increased mortality rate as a result of lung cancer in humans in highly air polluted areas; ten µm are equal to 0.000001 metres and such not visible with the human eye; (ABBEY, 1999). This study confirms that air pollution is harmful to humans. Taking into consideration this information one can understand why air purification is needed in certain areas.
Most commonly air purification is used in factory areas where there are high levels of air pollutants, hospitals where air pollutants could affect the recovery of patients and schools where air pollutants could affect the health of children. In short, they are highly required in urban areas. There are multiple types of air purifiers available worldwide. One can separate air purifiers into two categories: active and passive.

Active air purifiers are recognized as ionizers due to them releasing negative ions inside a house which will stick the harmful particles to earthed conductors (e.g. a wall). While these air purifiers can clear the air you, your children and your pets breath, they also add Ozone to the air. Ozone ($O3$), while commonly found in air with a concentration of approximately 0.000007%, is poisonous to living beings and can cause health problems when inhaled regularly.

On the opposite side of this are passive air purifiers. These purifiers come with a fan attached which moves the air through a series of filters which should remove 99% of indoor pollutants. Such machines also usually come with carbon filters which can remove harmful gases from where purified environment. (Honeywell, 2017). In this project we will be discussing passive air purifiers.

1.3 Fans

A fan is a mechanical machine which is used to create a flow within a fluid, most commonly a gas (e.g. air). This machine is made up of an arrangement of blades which rotates and acts on the air. Usually, the fan is powered by an electric motor but other options are also available.

Fans are commonly classified as axial fans (propeller fans), centrifugal fans (radial), mixed flow fans and cross-flow fans. Fans are separated into these four categories by the direction and the way air flows.

For axial fans the air flows parallel to the shaft. In opposition to this, for centrifugal fans, the air flows in a radial direction relative to the shaft. For mixed flow fans the air flows both axially and radially and for cross-flow fans the air flows in an inward direction and then in an outward radial direction (ToolBox, 2018). The shaft is the metal or plastic piece in a fan about which the blades rotate. Figure 1 presents a centrifugal and an axial and a centrifugal fan. The fans being displayed one next to the other makes it easier to see differences between them.

Figure 1: Centrifugal and Axial Fan (Savio, 2018)

For the purpose of this project axial fans were used because the author needed to achieve a higher air flow rate and a lower differential pressure.

Axial fans are characterised by the creation of an air flow through the fan. The spinning blades generate a pressure difference which produces an air flow between. (Design, 2018)

The main design parameters for axial fans are flow rate, differential pressure and efficiency. In this particular case the efficiency that is needed is characterized by the amount of particles the purification machine can expel from breathable air, not the specific fan efficiency.

In regards to performance differential pressure and air flow rate are very important. It can be noted that the higher the differential pressure is the stronger the air flow is. These two characteristics are generally laid out in a XY graph, with one axis being pressure difference and air flow rate the other. Between the two axes the performance curve takes form (pictured Figure 2), manufacturers usually marking select points where the efficiency is optimal. In conclusion, by studying the performance curve of a fan one can decide if the fan is fitted for a specific application or not, by picking out points in the graph.

In addition to the two characteristics mentioned above, the speed at which the fan rotates is also paramount. The speed, routinely referred to as rotations per minute (RPM), is directly proportionate to the pressure difference. Based on this, by adjusting the RPM, differential pressure and air flow rate can be set to a defined state. It is worth noting, that increasing the rotational speed of the fan will result in louder operation noise while also being high pitched (extremely annoying for human ears). This will be studied closer later in the thesis work.

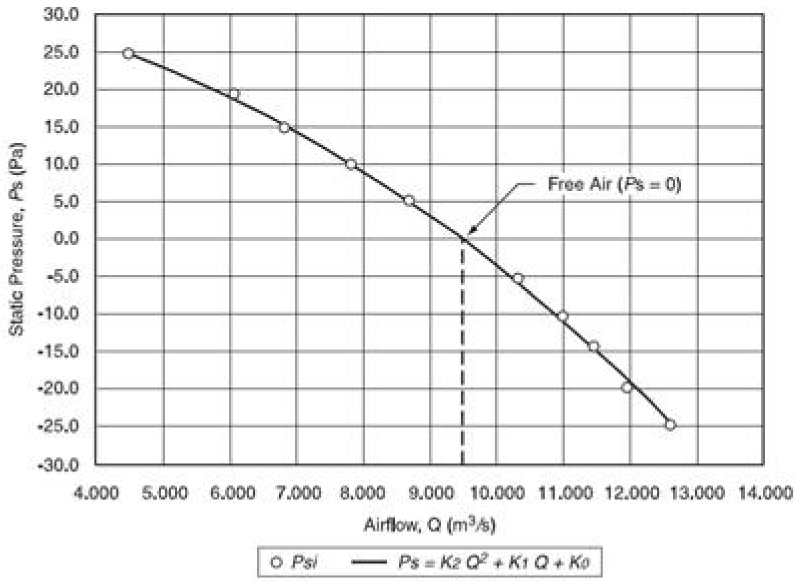

Figure 2: Performance Curve (AxAir, 2018)

Analogous to applications for axial fans, they are commonplace in every household, used to cool down on hot summer days. Other applications are wind tunnels, cooling towers and in this thesis as a way to move air to be purified. Due to a fans capability to move air in a specific direction fans are perfect for recreating “controlled” wind. Note that the word controlled is between quotation marks as there is no such thing as controlled wind.

An important point to make is that fans are loud. The size of the fan is directly proportional with the noise it make, thus we can conclude that the bigger the fan is or the bigger the fan blades are the more noise it will produce. This brings us unto our next topic of this thesis: noise pollution and how damaging it can be.

1.4 Noise Pollution

Noise (sound) pollution relates to high levels of noise that can be bothersome to the point of possibly inducing health issues, besides being aggravating to workers. When discussing all the types of pollution that are affecting our environment, noise pollution is rarely remembered, or even mentioned, despite the many problems it can cause. The health issues commonly associated with noise pollution concern the damaging of the auditory system such as hearing loss, perforated or scarred eardrums, etc. (Vossos, 2017). All of these can lead to a person becoming deaf.

Sound levels are measured using sound level meters, such as the Norsonic Precision Sound Analyser Nor140 (figure 7) which was used in this thesis. The measurement device is usually hand-held and connected to a microphone. The microphone, during a measuring phase, detects changes in air pressure made by sound waves (Meter, 2018). All of this must be in accordance to the acoustics standard ISO 3744:2010. In this case, one measurement phase is ten (10) second long.

Noise levels are measured in decibels (dB). The dB is a unit of measurement commonly used to express a change in value or absolute value. An interesting fact about this measurement unit, it is named in honour of Alexander Graham Bell from his power measurement in telephony in the 20th century. Decibels are used now in a variety of science and engineering measurements but most widely spread out in acoustics. Acoustics is a member of physics which is concerned with the study of mechanical waves in gases, liquid and solids. Also topics such as sound, ultrasound, infrasound and vibrations are included in this branch. (Acoustics, 2018).

To fully understand the measurement differences between sounds, a normal level conversation in a quiet environment e.g. at home is known to be at 50 dBs. The noise from a vacuum cleaner is noted to be at 70 dBs and at 150 dBs is the limit where an eardrum ruptures.

In conclusion it is favourable that an air purifier to be as quiet as possible in order to not disturb people while working, learning or recovering.

2 SEGREGATION OF THE PROJECT IN PHASES

The practical part of this project was separated into three distinct phases. The first phase is described as the empirical phase where the author examined and decided on what fans would be suitable for the project from the local market area.

The second phase is the test phase where the author gathers data based on multiple tests. These tests are applied to all of the fans, in the same manner, as to avoid discrepancy or the quote unquote comparing two different results.

The third and last phase is the analyse phase where the author evaluates the results from the previous phase in order to make an intelligent and comprehensive conclusion to the thesis.

2.1 Empirical Phase

The research phase is at first glance straightforward and maybe a bit obvious but the truth of it is that it was a longwinded road of learning. Due to this long process, it is now separated into four different stages: the challenges, the fans, the methods and the results. Each of these stages brought forward a test and excelling in each brought the results of a thought-out conclusion. In the following sub-chapters, each stage will be discussed.

2.1.1 Challenges

The first stage, the challenge stage, is made up of the revelation of what should be expected. This is based off a discussion with the commissioning party's representative on what the company (from here on mentioned as company X) would expect as a result. In short, company X requested that the fan in one of their air purifying machines be compared with other alternatives from the local market area. The reasons for this study is to find more cost efficient alternatives (from here on out the fan originally used is mentioned as FanX) since FanX is affecting the profit margin.

The main characteristics that are to be taken into account are Cost, Capability and Quality. It is made clear that the quality of the machine must be maintained or improved. In respect to the other two characteristics, the cost should be reduced and the capabilities should be similar to FanX. There are multiple combinations where even if the quality is set, the other two characteristics can fluctuate. One can have a greatly improved quality and capability, but the cost will adjust accordingly. More of such variables are possible.

In the discussion possible distributors for the fan were also mentioned. These distributors' names will remain anonymous and referred to as Distributor1 and Distributor2.

2.1.2 Fans

This stage is named the fans stage because it revolves around learning about fans in general and fan characteristics. This involves learning about fans and the specifications of each type. In addition to the basic information, research is gathered about fan testing. All of this theoretical knowledge is available and explained in Chapter 1, sub section 1.3.Fans and in the Subchapter 2.2. Test Phase.

This stage can also be nicknamed the "Learning Stage" because it involved in-depth learning on a new subject, scarcely covered during university courses.

2.1.3 Methods

The third stage focused in depth on research methods for fans which were just looked over in the previous stage. The author was given datasheets from FanX and from possible alternatives selected from Distributor1.

After the study of FanX's datasheets and base levels are determined, the other datasheets are studied. The characteristics of FanX are:

- Size, 280 millimetres
- Air flow rate, 1400 m^3/h
- Pressure, 240 Pascal
- One phase motor
- Six blades rotating clockwise

From the datasheets five fans were selected (from here on referred to as Fan1, Fan2, etc.). After the options from Distributor1 were taken into account, the focus is moved to Distrubutor2.

From Distributor2, preferred by company X, the customer website was used to select fans. In the website Distributor2 offered an online selection software for their clients. The author used the online selector because it is a much quicker way of viewing only the fans that match our criteria without having to sift through everything. The selector did the job for you. After the required account creation, the fan selector was used as such: in the selection criteria box 50 Hertz was selected, airflow was picked at 1400 m^3/h and pressure was picked at 240 Pascal. Next, the catalogue was selected, in this case the General Catalogue was broad enough as the application the fans are needed for are commercial and general use applications. From the catalogue, axial fans categories were chosen for the selector to go through. Making these selections ensures that only axial fans were selected, since centrifugal fans were not required in this process. The type of motor preferred was chosen next: one-phase. After all the above mentioned information was introduced, the selector started picking out fans.

The selector offered over 70 results based on the chosen criteria. The fans were moved to an excel sheet along with their specifications in order to be studied and possibly chosen for testing. After careful deliberation, the author decided that Distributor2 fans did not match the air purification machine in the size aspect (fans are either too big or too small) and as such no fan was picked to be tested. The size differences were too big to be able to fit the fans without adding big changes in the machine design. Having to change the design of the machine would have extended the period of this thesis and the time frame in which the fans can be tested is limited to just a month.

In total there were five fans to be tested but due to unforeseen circumstances only two are actually critiqued. One fan was duplicated by the distributor, another fan was too small and another fan was too thin. In the end one of the duplicates and another fan was tested. The tested fans were fit into the machine and were easily wired.

2.2 Test Phase

In this phase a number of tests are done on the selected fans in order to discover if they meet certain requirements, mentioned previously. The goal is that the fans have an appropriate air flow rate and differential pressure while maintaining a low enough sound level in order to not be disturbing. Several measurement instruments are used, each having a different purpose.

Five fans are selected to be tested from the get-go. On closer inspection of the fans, two of them are cut off. One fan turned out to be too small and it would have required huge structural changes to the purification machine. The other exempt fan broke during transportation to the laboratory and would not turn on, but luck was on our side since it was duplicated.

2.2.1 Instrumentation

A) CLiMET CI-454 Particle Counter

This instrument is a portable particle counter (Figure 3) which is primarily used to monitor pharmaceutically clean environments, compliant with ISO 14644.
This machine measures particles of four different sizes: 0.3, 0.5, 1.0 and 5.0 µm and prints out the results. It is programmed to do five tests owing to the need of possible inaccurate measurements. With five tests an average can be calculated that is most likely closest to the truth of the matter. (CLIMET Instruments Company, 2018).

This instrument was used only in testing FanX because it is more so testing the filter's capability than the fans'. First measuring the air that was going in the apparatus and then measuring the air that was coming out in order to test the air purifying capabilities. Since FanX is not the main purifying element, it was not used after this.

The results of the tests clearly showed that the air pushed out, the purified air, was cleaner since the number of particles lowered drastically, almost reaching no remaining particles. The results of this test can be found in the first three tables in this document. They are important to show the cleaning efficiency.

Figure 3: CLiMET CI-454 (CLIMET Instruments Company, 2018)

B) VelociCalc Scope Measurement

This instrument is an accurate air quality data logger (Figure 5). It is a hand-held device which uses a detachable hot wire sensor (Teknocalor, 2018).

This tool is used to measure air flow through a tube in five different points (Figure 4) in order to assess the true air flow rate. The flow is checked in the points marked in the following figure 5. Figure 6 shows what the measuring instruments looks like.

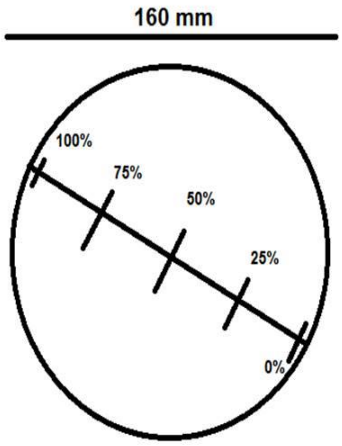

Figure 4: Point of Measurement (Makkonen, 2018)

Figure 5: Hot Wire Air Flow Measurement Device (Teknocalor, 2018)

The average of the five measurements is calculated to obtain the authentic flow rate. This measurement is done on all of the fans besides Fan1. Fan1 is not tested in this fashion because the machine overheats and stops after a couple of minutes, not allowing enough time for this test. When the purifying machine stops one has to go turn it off correctly, turn it back on and set again the correct fan speed. Three different fan speeds are set, and in such three different tests sessions are done.

The first test is at 200m^3/h, the second at 350 m^3/h and the third at 500m^3/h. The upper limit is set at 500 m^3/h for all the fans due to customer requirements.

C) Norsonic Precision Sound Analyser Nor140

This instrument is a hand-held precision sound analyser which is delivered with a microphone and a preamplifier (Figure 6) (Norsonic, 2018). The noise is registered by the microphone and the measurement is shown on the device's screen. All fans are tested with this instrument.

The tests are done as such: first, the machine with the fan installed in is set in a sound-proofed room, to obtain as accurate as possible measurements, next a base sound level is taken. After this the machine is turned on and set to the first speed (200 m^3/h) and the instrument is recording the sound with the microphone set at seven distances from the epicentre of the sound. This process is repeated with the two other speeds (350 and 500 m^3/h) without measuring background level and setting up the machine again and then with the two other fans.

The sound-proofed room is key in this measurement. Without it any evaluation of the noise would be erroneous due to background noise from computers, cars, people, etc.

Figure 6: Nor140 Sound Analyser (Norsonic, 2018)

2.3 **Analyse Phase**

In this phase, as one can tell by the name, happens the interpretation and break down of the results from the testing phase. The results from the previous phase are carefully transcribed and compared with FanX's results. In this subchapter one will go in depth into the testing outcome. At the end of the chapter, there will be an in-depth discussion of the results, in order to further understand the reasonings behind the conclusion.

2.3.1 Base measurements

This part contains five tables with the results of FanX's tests. The first table reflects the cleaning power (purification) of FanX, in three different speeds (200, 350 and 500 m^3/h), with four different particle sizes (0.3, 0.5, 1.0, and 5.0 µm) from five tests. In other words, measurements have been taken five times for each speed. This first table reflects the particle input (before purification), the second the particle output (after purification) and the third the cleaning power.

This particular test, conducted with the CLiMET CI-454, demonstrates clearly the cleaning capacity of the carbon filter installed in the purification machine. It is one of the strongest selling points for this machine and well deserved so.

Table 1: Particle Results Before Purification

Air Volume	Test 1 Input	Test 2 Input	Test 3 Input	Test 4 Input	Test 5 Input	AVG
	0.3 µm					
200	32927710	30689134	30830429	30415338	30344072	31041337
350	33848440	30929487	32068534	32933219	33463260	32647588
500	31952736	31115279	31264308	30744014	31159211	31247110
	0.5 µm					
200	2942754	2654902	2648510	2613655	2522642	2676493
350	3107110	2663449	2819858	2973725	3047710	2922370
500	2745556	2710029	2734855	2592324	2658257	2688204
	1.0 µm					
200	450935	403825	395208	384685	384685	412145
350	446097	397928	391536	381753	371853	399927
500	392454	375432	379599	342448	325744	363135
	5.0 µm					
200	7804	6109	8526	8616	6603	7532
350	7238	6286	5650	4838	4202	5643
500	5826	6427	5050	4944	4096	5269

Table 2: Particle Results After Purification

Air Volume	Test 1 Input	Test 2 Input	Test 3 Input	Test 4 Input	Test 5 Input	AVG
	0.3 µm					
200	76177	697080	700506	697327	724590	716256
350	3729146	3610206	3553246	3607910	3554796	3611060
500	3340788	3274114	3232230	3214290	3178234	3247931
	0.5 µm					
200	36374	34537	32666	35350	35138	34813
350	202530	189499	182401	197163	172118	190742
500	184908	169829	15750	166474	160470	170570
	1.0 µm					
200	3319	3637	2754	3672	2860	3248
350	23519	18752	18505	25250	17198	20645
500	20729	15079	15750	16103	13207	16174
	5.0 µm					
200	35	105	176	0	105	84
350	353	105	0	105	70	127
500	388	211	176	105	105	197

Table 3: Air Cleaning Power of FanX

Air Volume	Input Average	Output Average	Cleaning Power (%)
	0.3 µm		
200	31041337	716256	97.7
350	32647588	3611060	88.9
500	31247110	3247931	89.6
	0.5 µm		
200	2676493	34813	98.7
350	2922370	190742	93.5
500	2688204	170570	93.7
	1.0 µm		
200	412145	3248	99.2
350	399927	20645	94.8
500	363135	16174	95.5
	5.0 µm		
200	7532	84	98.9
350	5643	127	97.8
500	5269	197	96.3

The next table reflects the true air flow with the purification machine set at the three speeds. Five measurements in different points of the tube are taken to properly gage the air flow. This measurement is taken with the hot wire tool, through an air vent and then an average is calculated. The average is as close as we can get to the true value of the air flow rate flowing through an air vent. This table shows the five air speed measurements and the air flow results in cubic meters per second and cubic meters per hour. As these are the results from FanX, these are set as the standard values that should be achieved and all the other fans strive towards. Some of the values taken during the other fan measurements are slightly adjusted to reach the correct, the expected, results.

Table 4: True air flow of FanX

Measurement Number	200 m^3/h	350 m^3/h	500m^3/h	Results
1	0.76	1.6	2.4	0.040939 m^3/s 147.4 m^3/h
2	0.89	1.5	2.44	
3	0.98	1.35	1.9	0.078539 m^3/s 282.7 m^3/h
4	0.74	1.61	2.27	
5	0.74	1.94	3	0.117907 m^3/s 424.5 m^3/h
Average	0.834	1.6	2.402	

The last table of this sub-chapter is the sound level of FanX. For this seven measurements are taken for each air flow speed, each at a different distance from the machine. An in-depth explanation regarding the measurement machine used and how the measurement takes place you can find in sub-chapter 2.2.1, part C. Shortly, for this the Nor140 Sound Analyser is used and the base sound level is of approximately 20dB, with the machined turned off and only the author being in the sound proofed room. As noted previously, 20dB is similar to a whisper or leaves rustling, close enough to what the sound level should be in an office space.

Table 5: Sound Levels of FanX

Speed (m^3/h)	Distance (m)	Sound Measurements from Each Speed (dB)		
		200 m^3/h	350 m^3/h	500 m^3/h
	0.00	39.30	57.80	65.90
	0.50	36.10	49.30	58.80
	1.00	30.30	42.60	50.80
	1.50	27.60	39.90	47.10
	2.00	26.20	38.10	46.50
	2.50	25.00	36.60	45.00
	3.00	23.70	36.00	44.10

The following sub-chapters hold an in-depth look at the measurements taken from Fan1 and Fan2 and a detailed answer as to why some measurements are not taken, as they would take time from the already limited amount allocated for testing.

The only measurement no other fan was subjected to happens to be the particle measurement (reflected in the first three tables) because it is decided this offers more information regarding the purification power and not as much information for the fan.

2.3.2 Measurements of Fan1

Fan1 is difficult to work with. Once hooked up to the purification machine it caused it to overheat every couple of minutes. Due to the overheating, we could not make it run longer than a maximum of five minutes continuously. Once it overheated, the machine had to be stopped and restarted manually. Because of these issues with it only sound level measurements are taken, since this measurement does not require the machine to run continuously for more than a couple of minutes. The air flow measurement requires the fan to work, stabilize and then the air flow can be measured. Add into the equation the fact that this needs to happen with three speeds and one can understand why the air speed measurement is not pursued, considering also that the sound level measurement is the one which takes the longest to take and note down. The base sound level for this measurement is also approximately 20dB.

The table in this subchapter shows the sound level results.

Table 6: Sound Level of Fan1

Speed (m^3/h)	Distance (m)	Sound Measurements from Each Speed (dB)		
		200 m^3/h	350 m^3/h	500 m^3/h
	0.00	56.80	60.10	67.90
	0.50	45.70	49.50	57.80
	1.00	40.50	43.70	52.10
	1.50	38.10	41.40	49.00
	2.00	36.30	39.40	47.30
	2.50	34.40	37.70	45.40
	3.00	33.70	37.70	44.80

From comparing the sound level tables of FanX and Fan1, it is easily distinguishable that Fan1 is much too loud to be an appropriate replacement for FanX. Without the constant overhearing issue, which is possibly due to human error, and considering that it is easily noticeable without testing that Fan1 is much faster, it could have been considered appropriate after a purifying efficiency test to ensure that the extra speed does not move the harmful particles too quickly and stops them from adhering to the carbon filter.

2.3.3 Measurements of Fan2

For Fan2 we realized that we had a duplicate. The duplicate came in handy fast because one fan turned out to be broken during transportation. Once Fan2 is hooked up with the purification machine, there were no issues blocking the measurement taking. For this fan both air flow and sound level measurements are taken.

The first table details the true air flow and the second the sound level. To make everything smoother with the fan, a potentiometer is hooked up to start the fan. For 3 Volts (V) the fan gave 200 m^3/h, for 5 V it gave 350 m^3/h and for 7 V.5 500 m^3/h. By using the potentiometer it means that the speed could be manually selected without the use of the digital interface of the purification machine.

The use of the potentiometer is the main different between how the measurements for FanX and Fan2 are taken. The other, less striking difference, is that the author “played” a bit with the voltage measurements, in order to achieve similar speed results as the ones for FanX, in order to gather comparable data.

Table 7: Fan2 Air Flow Measurement Results1.

Measurement Number	200 m^3/h	350 m^3/h	500	Results
1	1.1	2.05	4.1	0.046142 m^3/s 166.1 m^3/h
2	0.9	1.85	3.6	
3	0.85	1.7	3.6	0.092284 m^3/s 332.2 m^3/h
4	0.9	1.8	2.87	
5	0.95	2	3.45	0.172983 m^3/s 622.7 m^3/h
Average	0.94	1.88	3.524	

From these first measurement results it can be seen that we are a bit off from the air flow we wanted. To correct this, we used 3.5 V and 7 V for the first and third speed. The results for the second speed were accurate enough and as such not changed.

Table 8: Fan2 Air Flow Measurement Results2

Measurement Number	200 m^3/h	350 m^3/h	500 m^3/h	Results
1	1.2	2.05	3.4	0.06234 m^3/s 224.4 m^3/h
2	1.1	1.85	3.1	
3	1.75	1.7	2.6	0.092284 m^3/s 332.2 m^3/h
4	1.15	1.8	3.3	
5	1.15	2	3	0.151188 m^3/s 544.3 m^3/h
Average	1.27	1.88	3.08	

These new results are much closer to the actual speed we want them to be and thus satisfactory. With these values we can carry out a proper comparison.

Table 9: Fan2 Sound Level Measurement Results

Speed (m^3/h)	Distance (m)	Sound Measurements from Each Speed (dB)		
		200 m^3/h or 3.3 V	350 m^3/h or 5 V	500 m^3/h or 7 V
	0.00	50.50	61.90	68.70
	0.50	43.20	54.30	59.60
	1.00	37.70	48.80	55.90
	1.50	35.30	46.20	53.00
	2.00	33.50	44.30	51.30
	2.50	31.70	42.70	49.40
	3.00	31.00	41.60	48.60

From the sound level results it is easily noticeable that Fan2 is much louder than bot FanX and Fan1. Due to this, even though as opposed to Fan1 it can run continuously, it is still not suitable as a replacement. In this case, similarly to FanX and Fan1, the base sound level is of approximately 20dB.

2.3.4 Discussion

In this sub-chapter the author displays the original values with the values gathered from Fan2, in a table, for a cleaner and visual representation. This helps the reader to understand visually the conclusions.
The first table exhibits the differences between true air flow rates.

Table 10: FanX and Fan2 True Air Flow Rate Comparison

Air Flow Rate	FanX	Fan2
200 m^3/h	147.4 m^3/h	224.4 m^3/h
350 m^3/h	282.7 m^3/h	332.2 m^3/h
500 m^3/h	424.5 m^3/h	544.3 m^3/h

It is easily distinguishable from the table that while both fans are close to the desired air flow rate, FanX is a bit slower, while Fan2 is much quicker. For the third speed, the difference between the two fans is of over 100 m^3/h. In this case, more adjustment are needed, to bring the values as close together as possible but due to the short time allocated, this is not possible.

In the next table, the sound level at each speed is showcased at a couple key distanced: 0 m, 1.5 m and 3 m. Please take into account that in a real-life situation, the machine would be placed in a corner of a hallway, possible more than 3 m distance from the closest person.

Table 11: FanX and Fan2 Sound Level Comparison

Air Flow Rate	0 m		1.5 m		3 m	
Fans	FanX	Fan2	FanX	Fan2	Fanx	Fan2
200 m^3/h	39.30	50.50	27.60	35.30	23.70	31.00
350 m^3/h	57.80	61.90	39.90	46.20	36.00	53.00
500 m^3/h	65.90	68.70	47.10	41.60	44.10	48.60

From table 11 it can be easily seen that Fan2 is much louder than FanX, but taking into account the air flow rate (speed) difference, it is understandable. Possibly, with more tuning of Fan2, these values will be much closer together.

3 CONCLUSIONS

3.1 Challenges

In this experiment the author was supposed to find a couple of fan options to test out in regards to Cost, Capability and Quality as a research of the local fan market area.

The cost part is taken out of the equation early on, after filtering and selecting fans which were more cost friendly than the one they originally used.

The quality part is also guaranteed since the samples are taken from well-known suppliers of fans and they promise the best quality for their products.

The capability is the only part which needed testing. A big aspect in regards to the testing, besides the noise level and air flow rate, is that the tested fans could fit into the machine. This is the first challenge that the author was met with and it resulted in a low number of samples that could be tested. For the fans to fit not only the actual diameter of the fan needed to be taken into account, but also how slim the fans are. The width (slimness) should also be an important factor. Some of the received for testing fans were not wide enough and due to that the whole physiology of the purification machine. To make such big changes to the machine requires a long time which the author did not have. In addition to this the company was not willing to do it. This cut down the number of fans to test by two.

The second challenge encountered is the delay for the fans to come. It took over a month for the samples to arrive to the testing facility thus limiting the time available for testing. All the testing is done in only a couple of days. Originally, one month is allocated to just testing the fans, but due to the arrival delay, the testing is packed tightly in just a couple of days.

The third challenge is the breaking of a fan during transportation. This once again cut down the number of fans to test by one. Luckily, the distributor send by accident two of the particular fan, and only one of them is broken. But this still limited the number of samples the author could test.

The fourth challenge to cross paths with was the wiring of the fans into the machine. The wiring required a lot of wire cutting and inserting into special slots. Multiple times the wiring was not correct and had to be redone. This set-back happens because of pure human error and it only cost a short amount of time from testing. After the first failed tries, everything moved quickly and correctly.

The fifth and last challenge encountered was that the purification machine could not work well with the fan, even after being correctly wired. This is seen in the testing phase of Fan1, where the machine did not agree with the fan and thus overheated, limiting the testing options.

3.2 Conclusion of the testing

Both fans that were capable to be tested turned out to be too disruptive to an average working environment.

Discussed previously in chapter 1 sub-chapter 1.4, loud and continuous sounds can be disruptive to humans at best and just downright harmful at worst. Of course, considering the air flow rate difference noted between FanX and Fan2, with a bit more time, the loudness issue could be evaluated better. Taking the loudness of the fans and the places where the machine would most likely go (hospitals, schools, offices etc.) it is just not plausible for the selected fans to be adequate replacements. Even if they could clean the air faster and better, the noise would just not let anything else happen in the near vicinity. But the question of the air quality is still hanging in the air, as it is plausible that with a faster air flow rate the air could either be cleaner or lacking.

In conclusion, the best option for Company X is to continue using FanX and maybe attempt in the future to remodel it. It is plausible that a smaller fan would not make as much noise and the fan technology is advancing.

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