A quiet, repairable metal air cleaner for inexpensive long-term disease prevention in public spaces

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Abstract: Cleaning indoor air can significantly reduce the spread of airborne diseases in public spaces, and is recommended under American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 241. We publish a public domain design for a hyper-efficient, near-silent, sturdy, repairable, easy to maintain, inexpensive and attractive portable air cleaner we name the DeisBox [deɪ-ɪs-bɒks] that can be mass produced and deployed by institutions managing shared indoor spaces like schools, offices and venues. Its efficiency is approximately twice or more that of comparable commercial units and it uses nonproprietary filters. We urge institutions to invest in the development and deployment of these air cleaners as low-hanging fruit with high modeled economic benefits in the prevention of disease and pursuit of public health.

MeSH keywords: Public Health, Air Filters, Indoor Air Pollution, Occupational Exposure, Air Microbiology, Sanitary Engineering

Introduction

Here we share a public domain design for a hyper-efficient, near-silent, sturdy, repairable, easy to maintain, inexpensive and attractive portable air cleaner we name the DeisBox [deɪ-ɪs-bɒks] (see Image 1) that can be mass produced and deployed by institutions managing shared indoor spaces like schools, offices and venues. Inspired by highly successful do-it-yourself air cleaners like the Corsi-Rosenthal box, the design presents multiple important advantages over, and indeed measurable superiority to existing commercial designs. It can also be resized to form the basis of a broader platform of air cleaners. We urge governments, public bodies, corporations and non-profit organizations to invest in the development and deployment of these air cleaners as low-hanging fruit with high return on investment in the prevention of disease and pursuit of public health.

Image 1: Assembled DeisBox

Why air cleaners can prevent disease and improve health

Since 2020, research has established that many harmful infectious diseases such as COVID-19, influenza and respiratory syntactical virus are transmitted in aerosolized form and particularly indoors.[1,2,3] People spend about 90% of their time indoors.[4] Airborne diseases and indoor pollution cause widespread economic harm, suffering, disability and death.

Exposure time to aerosolized pathogens is positively correlated to probability of infection,[5] meaning transmission will decrease precipitously when indoor air is continuously cleaned or replaced at a sufficient rate. It is possible that doing so in all public indoor spaces could reduce the rate of transmission for some infectious diseases below 1.0 per infection, potentially leading to exponential decay of pathogens and greatly reducing seasonal epidemics.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers' [ASHRAE's] release of ASHRAE Standard 241: Control of Infectious Aerosols in 2023 establishes new minimum air quality requirements for reducing the risk of airborne disease transmission indoors.[6] The standard seeks to lower and equalize risk of airborne disease transmission in indoor spaces by specifying how much clean air is required per person in different occupancy categories. Notably, healthcare waiting rooms have the highest required equivalent clean airflow per person. Conservative modeling of ASHRAE Standard 241 estimates economic benefits of wide implementation at an order of magnitude greater than the costs, and in the tens of billions of dollars annually in the United States alone.[7]

Historical ventilation standards are insufficient to meet ASHRAE Standard 241 and control the spread of airborne diseases, though real world performance of ventilation systems can often be somewhat improved by changing settings and upgrading filters. For many institutions, expensive ventilation system overhauls are limited by budgetary restraints. Widespread deployment of affordable and effective portable air cleaners is thus important to meet ASHRAE Standard 241.[8] These cleaners also serve as a form of climate adaptation, removing wildfire smoke, allergens and other harmful pollutants from the air.

DeisBox: an excellent institutional air cleaner that uses simple existing technology

Key characteristics of ideal institutional air cleaners include high energy efficiency, high Clean Air Delivery Rate [CADR], low noise, durability, repairability and low operating cost. Many commercially available and industrial air cleaners are loud (and thus turned down or off by occupants), expensive relative to performance, non-repairable and costly to operate due to proprietary filters which are monopolized and carry risk of discontinuation, planned obsolescence and unavailability.

Here we present an extremely promising air cleaner design for many public and institutional applications: the DeisBox, a metal construction computer fan-based air cleaner that uses nonproprietary MERV-13 furnace filters. It was first created by author Zack Deis, a corporate health and safety manager from Edmonton, Alberta, Canada who based the fan layout on optimization testing by Robert Wissmann. Deis made the plans public domain in 2023 and we provide them here (see Supplemental Materials for frame plans in PDF, SolidWorks and .STEP formats). This design can be easily modified to accommodate larger filter sizes and increase per-device CADR, and Deis is currently developing a larger cuboid design with higher CADR.

Text Box 1 summarizes our performance testing of the unit. Table 1 summarizes comparative advantages of this design.

Text Box 1: DeisBox Testing Methodology and Results

Testing completed by author David Elfstrom, P. Eng.

Methods

The tested configuration of the DeisBox used two 20x20x2 AAF Flanders PREpleat® M13 MERV-13 filters and six Arctic P14 PWM PST fans.

A portable greenhouse made from a steel frame with polyethylene sheeting of volume 584 cubic feet was sealed to minimize air leakage. A floor fan (Honeywell model HT900) was operated throughout the experiment to continuously mix the air in the chamber.

For each trial, a consumer respiratory therapy compressor was operated for a duration of approximately 3 seconds to aerosolize a solution of 100 g/L sodium chloride (pickling salt) in reverse osmosis filtered water, without charge neutralization.

A Temtop PMD-331 6-channel optical particle counter was used to measure the count of all particles 0.3 µm and larger. The initial starting concentration of particles 0.3 µm and above was targeted at 27000/L to prevent increasingly non-linear response by the particle counter at higher concentrations. The starting count median optical diameter for the aerosol was 0.8 µm based on a lognormal distribution, using the midpoint of each size channel. The use of 0.3+ µm salt aerosol approximates the particle sizes of fine infectious aerosols, which experimental studies have shown contain the majority of the viral load exhaled by patients with COVID-19.[9,10]

The procedure used is a modified drawdown experiment described in ANSI/AHAM AC-1 2020.[11] The difference between aerosol removal rate with the air cleaner operating and the natural background removal rate with the air cleaner turned off was multiplied by the chamber

volume to obtain the Clean Air Delivery Rate. The procedure was first verified on a commercial air cleaner (Honeywell HPA5350BC), which matched the published independent test in the AHAM directory, within 2%. Then, the procedure was applied to the DeisBox.

Results

CADR: 282.9 CFM, 95% CI [280.9-284.9] for 0.3+ μm salt aerosol (0.8 μm median count diameter; three trials).

Power draw: 8.4 W, measured with a HOBO UX120-018 plug load power meter.

Efficiency: 33.7 CFM CADR/W.

Table 1: Advantages of DeisBox compared with Typical Commercial HEPA Air Cleaner

Key Portable Air Cleaner Attributes	DeisBox	Commercial Institutional HEPA Air Cleaner
Cost	$$	$$-$$$$
Cost to Operate	$	$$$-$$$$
Clean Air Delivery Rate (CADR)	282.9 CFM +/- 2.0 CFM	Varies, similar CADR units are priced higher with louder operating noise
Energy Efficiency per CADR	33.7 CADR/watt (salt)	Max 13.8 CADR / watt (smoke) as per Energy Star database
Filter Type	Inexpensive MERV-13 furnace filters	Expensive proprietary filters (unavailability risk)
Operating Noise for Similar CADR	~40-42 dbA (e.g. quiet library sounds)	~50-55 dbA (e.g. normal conversation)
Repairability	Fully repairable (replaceable 140mm computer fans)	Varies, often non-repairable
Frame Construction	Metal (Aluminum or Steel)	Plastic, sometimes metal

The DeisBox is a rectangular box approximately 9.5” wide by 21.25” long by 20.25” tall (~24cm x 54cm x 51cm). The main enclosure is entirely metal - coated aluminum has been used, or steel in the case of company Nukit’s commercialized Tempest model which used the DeisBox open

platform as a design starting point. The enclosure should withstand decades of continuous operation in public spaces.

The DeisBox accepts two universal 20”x20”x2” (51cm x 51cm x 5cm) MERV-13 furnace filters, which are covered by perforated panels that act as aesthetically pleasing prefilters. The top and one side incorporate a total of six 140mm computer fans to generate airflow. In this instance Arctic P14 PWM PST fans are used, generating a CADR of 282.9 CFM, 95% CI [280.9-284.9] for 0.3+ μm salt. Arctic warranties their fans for six years, and computer fans can continue to operate normally for decades.

Importantly, this design presents very large gains in energy efficiency when compared to commercially available room air cleaners. The unit draws 8.4 watts. We measure an estimated 33.7 CFM CADR/W for 0.3+ μm salt / watt (and approximate ~26 CFM CADR/W for smoke), representing potentially nearly double the efficiency of the highest-rated room air cleaner certified by Energy Star as of October 2024 (13.8 CFM CADR for smoke/watt), particularly for particles sizes similar to aerosols found to be most infectious.[9,10,12] The DeisBox’s hyper-efficiency generates large cost-savings and reductions in environmental impact for long term institutional use, as does the use of nonproprietary furnace filters.

The air cleaner runs at a single maximum speed, preventing room occupants from inappropriately adjusting flow rate. Noise levels are approximately 40-42 dbA, 5-15 dbA lower than comparable commercially available units and unobtrusive even to quiet conversation. Low noise means the number of units can be matched to room and occupancy requirements established by ASHRAE Standard 241 to enable high clean airflow rates without attracting noise complaints, a common reason air cleaners are turned down or off.

The use of a fan array in lieu of a single larger fan permits lower fan RPM, greatly reducing noise while maintaining high airflow. Similarly, MERV-13 filters permit high air flow and low noise compared to HEPA H11 or higher filters, while being less expensive and still enabling equivalent or higher CADR, the key measure of air cleaning for particles.[13] The higher throughput compared with high-resistance HEPA air cleaners may also contribute to quicker dispersion of short range aerosols, though this should be further modeled.

Repairability is high. If a fan fails the unit can be repaired with a similar 140 mm computer fan. The design omits a screen, motherboard and controls, all of which would add cost and create future failure points with no performance benefit. Inexpensive smart plugs can be used to program and monitor operation of these air cleaners across facilities. Battery powered alarms could trigger when units are unplugged to ensure continuing operation, as has been incorporated by the noted Nukit Tempest design.

The simplicity of this design means production is easily scalable. Sale price for current designs, though some assembly is required, is already less than half that of many comparable CADR but largely inferior industrial-grade air cleaners.

The DeisBox air cleaner exhibits long term durability, high repairability, impressive performance and low operating cost. The measurable advantages of this design platform (see Image 2 for an example of a larger design using this platform), particularly for environments like classrooms where noise levels and operating costs can dictate ongoing use, means that governments, investors and non-profits should direct funds to its development (refining the design, obtaining relevant certifications, etc), construction and deployment. Notably, this air cleaner can also be assembled as a simple STEM project for young students aged 10 and up. Additionally, filter replacement is simple, ensuring viability for long term use without significant ongoing labor commitments.

Institutions who deploy these air cleaners position themselves for decades of improved occupant health and all the benefits that will flow from meeting or surpassing ASHRAE Standard 241. If we deploy these devices, they can change the world for the better.

Image 2: Nine Fan, Four Filter DeisBox with Predicted CADR >500CFM (TBD)

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Supplementary Materials

1 – Deisbox Parts List and Basic Assembly Guide
2 – DeisBox Enclosure Design Specifications (PDF, Solidworks and .STEP files)

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