Design and construction of a low cost air purifier for killing harmful airborne microorganisms using a combination of a strong multi-directional electric-field and an ultra violet light

D.N.P. Ruwan Jayakantha\textsuperscript{a,b}, H.M.N. Bandara\textsuperscript{c}, Nadeesha M. Gunawardana\textsuperscript{c}, R.P.V. Jayantha Rajapakse\textsuperscript{d}, Dulari S. Thilakarathne\textsuperscript{d}, Elisabetta Comini\textsuperscript{b,*}, Nanda Gunawardhana\textsuperscript{a,*}, S.M.M.L. Karunarathne\textsuperscript{a,c,*}

\textsuperscript{a}Office of Research and International Affairs, Sri Lanka Technological Campus, Padukka, Sri Lanka
\textsuperscript{b}Sensor Lab, Department of Information Engineering, Brescia University, Brescia 25133, Italy
\textsuperscript{c}Faculty of Science, University of Peradeniya, Sri Lanka
\textsuperscript{d}Department of Veterinary Pathobiology, Faculty of Veterinary Medicine & Animal Science, University of Peradeniya, Peradeniya 20400, Sri Lanka
\textsuperscript{e}Faculty of Engineering, Sri Lanka Technological Campus, Padukka, Sri Lanka

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\textbf{A B S T R A C T}

In this work we have designed and developed a low cost and simple instrument to purify air in an enclosure. The device sucks up the air in the enclosed area, kills the microorganisms and let clean air flow out. A combination of an ultra violet light and an electric field are used to kill the microorganisms in air. Three electric field chambers (radial, parallel, perpendicular) are used to clean air more effectively. Stainless steel meshes were used to increase the density of the electric fields. The outer covers were made with plastic and wood. The instrument was tested against an evaporated bacterial solution (Staphylococcus aureus) by letting it flow through the instrument and measuring the bacterial concentration of the output air. The results showed the instrument is extremely effective even when tested against high bacterial concentrations. The instrument is extremely useful to clean air in closed rooms such as in hospitals, schools, etc. and prevent the spread of airborne diseases.

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\section*{Specifications table}

\begin{tabular}{|l|l|}
\hline
\textbf{Hardware name} & UV assisted multi-electric field air purifier \\
\hline
\textbf{Subject area} & \textbf{Engineering and materials science} \\
& Chemistry and biochemistry \\
\hline
\end{tabular}

(continued on next page)
Hardware name | UV assisted multi-electric field air purifier
--- | ---
Hardware type
- Medical (e.g., pharmaceutical science)
- Neuroscience
- Biological sciences (e.g., microbiology and biochemistry)
- Environmental, planetary and agricultural sciences
- Educational tools and open source alternatives to existing infrastructure
- General
- Imaging tools
- Measuring physical properties and in-lab sensors
- Biological sample handling and preparation
- Field measurements and sensors
- Electrical engineering and computer science
- Mechanical engineering and materials science
- Other [Electronic and design]
Closest commercial analog | LG Signature 3-Speed (Covers: 316 Sq.-ft) Non-HEPA and UV White Air Purifier
Open source license | CERN Open Hardware License v2
Cost of hardware | 120 $
The radial electric field was created using two cylindrical type mesh networks inside a polyvinyl chloride (PVC) tube (Fig. 2c). The meshes have many wire crossing points which have a high charge density. This increases the probability of attracting any charged microorganisms. The distance between two meshes was maintained at a level which make sure there are no sparks created. Absence of sparks are important to avoid ozone production inside the machine.

Most of the existing machines with air cleaning components use a UV light. The high electric field is more efficient in killing microorganisms and hence the combination of UV light and electric field leads to an ideal air cleaner. By using a powerful blower or by moving the instrument it can be applied to clean air in larger indoor areas. The low cost (120 $) of the instrument makes it even more attractive compared to the available commercial products in the market (1700 $) and the development process is extremely simple and can be achieved under minimum lab facilities.

- The E-Field/UV air purifier could be used to kill viruses in air and would be ideal for use in closed rooms.
- The E-Field/UV air purifier technology can be applied to any air conditioner machine.
In biomedical research the resistivity of any microorganism can be tested using E-Field/UV air purifier.

The calculated air flow rate of the instrument was 0.188 m³ s⁻¹. The residence time in each chamber is as follows. Parallel chamber 0.042 s, Perpendicular chamber 0.042 s, Radial chamber 0.0229 s. We used an anemometer (AM 4201) to measure the air speed when calculating above parameters.

**Design files summary**

| Design file name | File type          | Open source license               | Location of the file                                      |
|------------------|--------------------|-----------------------------------|---------------------------------------------------------|
| Fig. 1           | Power point figure | CERN Open Hardware License v2     | Available with the article as a figure and a separate editable power point file is attached |
| Fig. 2           | Power point figure | CERN Open Hardware License v2     | Available with the article as a figure and a separate editable power point file is attached |

**Bill of materials summary**

| Designator/Image | Component                     | Number | Cost per unit -currency | Total cost –currency | Source of materials | Material type    |
|------------------|-------------------------------|--------|-------------------------|----------------------|---------------------|------------------|
|                  | High voltage generator       | 1      | LKR 3000 (15 $)         | LKR 3000 (15 $)      | –                   | Non-specific     |
|                  | UV lamp (9 W)                 | 1      | LKR 4000 (20 $)         | LKR 4000 (20 $)      | –                   | Non-specific     |
|                  | Stainless steel mesh (10×10 cm) | 6      | LKR 700 (3.5 $)         | LKR 4200 (21 $)      | –                   | Metal            |
|                  | Silicone glue                | 1      | LKR 400 (2 $)           | LKR 400 (2 $)        | –                   | Organic          |
|                  | Fan Blower                   | 1      | LKR 5000 (25 $)         | LKR 5000 (25 $)      | –                   | Non-specific     |
Designator/Image Component Number Cost per unit -currency Total cost – currency Source of materials Material type

PVC T-socket (Diameter 10 cm) 1 LKR 500 (2.5 $) LKR 500 (2.5 $) – Organic

Second hand PC Power supply unit 1 LKR 1500 (7.5 $) LKR 1500 (7.5 $) – Non-specific

PVC conduit pipe 1 LKR 20 (0.1 $) LKR 20 (0.1 $) – Organic

Switch/Wires/Wooden parts/ Stickers/Nuts and bolts 1 LKR 2000 (10 $) LKR 2000 (10 $) – Non-specific

Build instructions

The following instructions will guide any user to fully assemble the proposed E-Field/UV air purifier in this article.

**Step-01:** The mesh frames and networks to use in the high electric field chambers (Parallel, Perpendicular) were completed by fixing a wooden frame around each stainless steel mesh (Fig. 1a).

**Step-02:** The frames were fixed inside the main wooden frame to make the parallel and perpendicular electric fields (Fig. 1b). The edges and connections were made airtight using silicone glue. The gap between meshes in electric fields was fixed at around 3 cm.

**Step-03:** Outer enclosure and chambers were constructed using wooden frames (Fig. 1b). Each chamber was separated using wooden sheets and silicone glue was applied to the joints to avoid air leaks.

**Step-04:** The blower was fixed in the middle of the chamber (Fig. 1c).

**Step-05:** UV light was fixed in the chamber in between blower and parallel electric field chamber.

The high voltage generator was fixed in the chamber (Fig. 1d).

**Step-06:** The radial electric field chamber was created by creating two cylinders with a stainless steel meshes and inserting them in a PVC tube. Small diameter cylinder (‘-’ve terminal) was wound around a PVC conduit pipe (diameter 1.5 cm) and inserted in the middle of the tube with larger diameter (10 cm) and the large diameter cylinder (‘+’ve tube) was inserted closer to the wall of the tube (Fig. 1e).

**Step-07:** The high voltage generator was inserted and connected to all three electric field chambers and the power supply was inserted and connected to the generator.

**Step-08:** Finally, an insulating sticker was used to cover the outer body of the instrument.

The insulation is extremely important since a high electric field is present inside the instrument.

Operation instructions

Operation of the instrument is simple and straightforward. Once the power is switched on, the instrument will start to suck in unpurified air from the environment and will pump out clean air.

As the instrument contains a high electric field, care should be taken to keep it away from any wet conditions. If the instrument is damaged it should not be used until fixed. While the instrument is in operation, no attempts should be made to adjust any internal components.

Validation and characterization

Methodology

*Staphylococcus aureus* ATCC strain 25,923 was streaked on blood agar and incubated at 37 °C for 24 hrs. A bacterial suspension (neat) was made by dissolving 10 colonies of bacteria in 10 mL of phosphate-buffered saline (PBS). A 10-fold serial
dilution was made using PBS as the diluent. The neat and the first 3 dilutions \(10^{-1}, 10^{-2}, \text{ and } 10^{-3}\) were used for the experiment. The aerobic plate count (APC) of the neat was determined as previously described [27].

Each of the bacterial suspensions was sprayed into the inlet of the instrument. A single spray delivered 0.5 μL of the bacterial suspension into the device. The flow of air coming through the outlet following a single spray was captured to a blood agar plate by holding the plate against the airflow for 2 min. One at a time a single spray of each suspension was subjected to four conditions: without the activity of UV radiation and electric field (control), with the activity of UV radiation only, with the activity of electric field only, and with the activity of UV radiation and the electric field. To remove any residual effect from the previously applied UV radiation or the electric field, the device was turned off for 2 min between consecutive sprays. Triplicate of plates were used to assess the effect of each combination, the suspension, and the condition. After capturing the bacteria in the airflow coming through the outlet, plates were incubated at 37 °C for 18 hrs. Colony counts were obtained to determine the capacity of the device in reducing the bacterial load. Minitab statistical software version 18 (Minitab Pty Ltd, Sydney, Australia) was used to perform statistical analysis. Comparison of colony-forming units (CFU) between conditions was done using paired T-test. A P-value < 0.05 was considered statistically significant.

Results and discussion

As expected the device substantially reduced the bacteria in the airflow. The aerobic plate count of the neat was \(6.64 \times 10^8\) CFU per milliliter. The two conditions; the control and the activity of UV radiation only, yielded CFU that are impractical to count. It is convincing that the activity of UV radiation used in this device itself was inadequate in reducing bacterial counts to a notable level. However, following the application of the electric field only an obvious reduction in CFU was observed compared to that of the control or treatment with UV radiation only. The activity of UV radiation and electric field together significantly (P = 0.04) reduced CFU compared to that of the activity of the electric field only (Table 1).

The species of bacteria chosen for this experiment, *Staphylococcus aureus*, is usually found in air as a contaminant [28]. The bacterial load given to the device in this experiment is substantially above the number of bacteria normally found in the contaminated air [29]. Active air sampling in an enclosed environment with the use of an air sampler would be the ideal approach to assess the effect of the device but such an experiment will fail to determine the capacity of the device in reducing bacterial counts [30]. From the experiment conducted herein, it is evident that the electric field used in this device substantially reduces the counts of bacteria in the airflow and an augmented effect can be achieved by combining the effect of UV radiation with the voltage (Fig. 3).

![Fig. 3. The bacterial growth variation for air with different bacterial concentrations, with and without electric field and UV light.](image-url)

| Dilution | Mean bacterial colony counts observed at the end of incubation at 37 °C for 18 hrs. |
|----------|--------------------------------------------------------------------------------|
|          | without the activity of UV radiation and electric field | with the activity of UV radiation only | with the activity of electric field only | with the activity of UV radiation and electric field |
| Neat     | TNC \* | TNC | 224 | 210 |
| \(10^{-1}\) | TNC | TNC | 161 | 140 |
| \(10^{-2}\) | TNC | TNC | 90 | 75 |
| \(10^{-3}\) | TNC | TNC | 78 | 10 |

\* TNC: Too numerous to count.
As the experiment have shown clearly that the instrument is successful in removing bacterial microorganisms in air. Also the usage of the multidirectional electric field has proven to be effective than any normal unidirectional electric field. The design of the instrument is simple and the manufacturing cost is low. Due to the high electric field caution should be taken going to be the most prioritize future work/research with this instrument. Apart from that the instrument can be used as a research instrument to study how microorganisms behave in various types of electric fields.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ruwan Jayakantha received his B.Sc and M.Phil. degrees in 2010 and 2016 from University of Peradeniya, Sri Lanka. He is currently working as a research assistant in the Sri Lanka Technological Campus. He is also doing a Ph.D. at Brescia University. His research interests include, Electronics, Mechanics, Nano Technology and Computational Physics. He has received several patents for designing instruments such as, Pressure analyzer for measuring breathability, Specific surface area analyzer for powder materials.

Dr. Nanda Gunawardhana is the Director of Research and International Relations at Sri Lanka Technological Campus (SLTC). Nanda obtained his Bachelor's degree from University of Peradeniya, Sri Lanka and Ph.D from Baylor University, Texas, USA. He has completed two post-doctoral fellowships in Saga University and Fukuoka Industry and Science Foundation, Japan. He was awarded as the best young scientist in Sri Lanka in 2015 by National Science Foundation and TWAS, Italy and recipient of Prestigious Presidential awards for his scientific publications. He has published more than 100 papers and communications and delivered key-note speeches in many international conferences.

HMN Bandara received his B.Sc. from university of Peradeniya and Ph.D. from University of Aston. He is currently working in University of Peradeniya, Sri Lanka as an emeritus professor. His research areas include, Materials Chemistry, Polymer Chemistry, Nanocomposites, Nanotechnology, Solar Cells, Material Characterization, Polymers, Conducting Polymers and Dyes. He is an expert in instrument design and automation and has several patents.

Elisabetta Comini received her degree in physics at the University of Pisa in 1996 and Ph.D. degree in material science at the University of Brescia. Since 2016 she is working as a full professor at Brescia University. She has published more than 387 papers in leading scientific journals. EC is a researcher specialist in the growth of metal oxides, particularly nanowires, thin films and the measurement of their electronic, functional and structural properties. EC is the director of SENSOR laboratory (Brescia University, http://sensor.unibs.it) and is a co-founder of NASYS. Her Hirsch index (h-index) is 54 (Web of Science), 57 (Scopus), 64 (Google scholar).
Nadeesha Gunawardana received his M.Sc in NanoScience and NanoTechnology from Postgraduate Institute of Science University of Peradeniya in 2018. He has over five years of research experience. He served as a research assistant of projects supercapacitor and flow battery for four years, funded by CodeGen international. His research interests are focused on energy production and storage with aid of nano-materials. It includes synthesize graphene, graphene oxide, expanded graphite, and energy storage using supercapacitors and batteries.

Migara Karunarathne received his Ph.D from Sungkyunkwan university 2018. He is currently working in Sri Lanka Technological Campus as a senior lecturer. His research interests include study on the behaviour of liquid crystal materials and their applications in optics, Zinc Oxide nanoparticles based Dye sensitized solar cells, Waste management, Optical vortex arrays. Currently he is working on designing instruments and energy harvesting. His publications includes several subject areas including liquid crystal materials, dye solar cells and instrument design.

Prof. Jayanthe Rajapakse is a senior professor attached to Department of Veterinary Pathobiology, Faculty of Veterinary Medicine and Animal sciences, University of Peradeniya. He is a research expert in the field of veterinary science. He has published over 238 research articles which have been cited by 2753 researchers around the world. Prof. Rajapakse’s research primarily focuses on parasites of veterinary and medical importance. Other than that he has investigated zoonotic and vector borne pathogens in Sri Lanka. His works also include exploring pathogens of wildlife and therapeutic properties in herbal extracts. Prof. Rajapakse is an expert developing vaccines against parasites and he owns patents for developing anticancer therapeutics and antivenin for snake envenomation in Sri Lanka.

Dr. Dulari Thilakarathne completed her doctorate from University of Melbourne and currently works as an early career researcher attached to Department of Veterinary Pathobiology, Faculty of Veterinary Medicine and Animal sciences, University of Peradeniya. Her field of expertise is virology and her research interest include zoonotic and vector borne intracellular parasites.