Development of High-Performance Air Purifier using Human Hair and Vetiver (*Chrysopogon Zizanioides*) as Filter Media

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Development of High-Performance Air Purifier using Human Hair and Vetiver (*Chrysopogan Zizanioides*) as Filter Media

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ABSTRACT

Purpose-The global crisis of extreme air pollution is encountered nowadays due to the burning of fossil fuel, vehicular emission, modern sophistication and industrialization. These result infusions of high levels of Smoke, Particulate Matter (PM), Total volatile organic compounds (VOC), Hydrocarbons (HCHO), Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), Carbon Monoxide (CO) and other air pollutants into the atmosphere.

Findings- Therefore, the development of a cost-saving air purifier is extremely essential with naturally occurring resources that are readily available throughout all the places at some point in time. A compact, flexible, modular and low-cost air purifier has designed employing a combination of porous plug and two filter media developed from natural resources.

Methodology-The air purification unit is horizontal shaped and made with a simple PVC pipe. The first filter media was developed by mixing human hair with low-cost vegetable Mahua oil and the second one by wetting Vetiver (*Chrysopogan zizanioides*) with water. A mixture of human hair with Mahua oil can absorb the suspended particulate matter of size above 2.5 µm, and wet Vetiver shows the enormous capability of absorption of gases like NO_x, SO_x and Hydrocarbons and adsorption of particle size even less than 2.5 µm like PM1. Moreover, due to the pleasant smell, wet Vetiver can produce fresh air.

Value-The cleaning and disposals of such naturally derived products are easy because of complete biodegradability and no negative impact on the environment. To restrict the filter media movement, porous plugs are coupled at the inlets and outlets of pipeline and filters. Due to the Joule-Thomson effect, the air coming out of the porous plug becomes 50°C cooler than the input air. The pollutant removal efficiency of indoor was found to be more than 60% were in the outdoor residential areas, it was more than 75%, and in the heavily crowded regions, it evaluated to be more than 65%. Amidst the alarming air pollution scenario throughout the world, such an invented device should be welcome due to the excellent performance as reflected in the production of pollutant-free fresh air at reduced temperature.

Keywords: Air pollution,Particulate Matter (PM),Total volatile organic compounds (VOC), Air Purifier, Human Hair, Vetiver.

1.INTRODUCTION

1.1AIR POLLUTION

In India air pollution is a severe issue, with the primary sources being fuel adulteration, vehicular emission and traffic congestion (A.B. Ozturk, et al. 2011) (Akarsh Verma, V.K. et al. 2016). The burning of fossil fuels releases high levels of Smoke, Particulate Matter (PM), Total volatile organic compounds (VOC), Hydrocarbons (HCHO), Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), Carbon Monoxide (CO) and other air pollutants into the atmosphere (Angus Shiue, et al. 2019). Therefore, with worsening air quality, it is essential that we have to be aware of the quality of air that we breathing (Annie Melinda Paz-Alberto, et al. 2013). Exposure to particulate matter for a long time can lead to respiratory and cardiovascular diseases (M. Sharma, et al. 2003). Every year over a million Indians die prematurely due to particle pollution (D. Balasankar, et al. 2013). Therefore, it becomes necessary to purify the air in public areas where the pollution levels are exceeding the prescribed standards (Fortoul, T.I. et al., 2011).

2.LITERATURE REVIEW

Sl.No.	Author's	Findings	Interpretation
1.	Aditya Roy et al.(2019)	The various conventional and effective methods to filter PM 2.5 by using Activated carbon,Transparent PAN filter,s Photocatalytic materials and Soy proteins and silk nanofibrils.	The various general and modern methods of air purification were studied and reviewed. And also noted that from future scope combination will be a economical solutions.
2.	Akarsh Verma et al.(2016)	The humar hairs mechanical properties,chemical experiment of human hair fiber,thermal analysis anf ecological importance are reviewed.	The study of different characteristics of human hair and its application employed and also hair regains its original position after removal of the deformed load.
3.	Negisa Darajeh et al.(2014)	To demonstrate the potential of Vetiver grass in reducing the biological oxygen demand (BOD) and chemical oxygen demand (COD) and investigate biomass production.	The detailed study of vetiver wastewater treatment system and different characteristics of vetiver grass.
4.	Emily Cheek et al.(2020)	To observe the effect of portable air purifiers (PAPs) on indoor air quality (PM _{2.5}) of between 22.6 and 92.0% with the use of PAPs when compared to the control.	A detailed study on how the PAP results in short-term reductions in PM _{2.5} in the indoor environment.
5.	Julie F. Hart et al. (2011)	To evaluate the value of a portable air purifier in decreasing particle concentrations accompanying with wood combustion.	the effectiveness of an electrostatic filter portable air purifier was studied.
6.	C Pedroletti et al. (2009)	To examine the Exposure to breathe in allergens is a pathogenetic feature in allergic asthma. But, most studies that earlier looked at air cleaning devices have shown little or no effect on patients with perennial allergic asthma.	The detailed study of the clean air during sleep with the influenced factor
7.	V. P. Singh(2017)	To overcome these toxic waste atmosphere situations the concept of using plants for remediation of water, soil and air pollution.	A detailed study on Phytoremediation as acleaning tool for pollutants.
8.	Vannan Kandi Vijayan et al. (2015)	This journal discussesing the effect of air pollutants with special focus on indoor air pollutants and the benefits of air filters in improving indoor air quality.	The detailed study on indoor and outdoor air pollutant with its contamination.
9.	N Yamamoto et al. (2010)	To report approximately 500 indoor-outdoor air exchange rate (AER) calculations based on measurements conducted in residences in three US metropolitan areas in 1999-2001	Studied various quantitative and qualitative data to characterize residential AERs in three US urban areas with different climate attributes
10.	Zhe Wang et al.(2016)	To introducing Hybrid poly(lactic acid)/titania (PLA/TiO ₂) fibrous membranes exhibiting excellent air filtration performance and good antibacterial activity were prepared via the electrospinning technique.	Studied the result of prepared PLA/TiO ₂ fibrous membrane loaded with 1.75 wt% TiO ₂ nanoparticles formed at a relative humidity of 45% exhibited a high filtration efficiency (99.996%) and a relatively low pressure drop (128.7 Pa), as well as a high antibacterial activity of 99.5%.

Research gap: This research is a new innovative idea of development of high-performance air purifier using human hair and vetiver (*Chrysopogon zizanioides*) as filter media.

2.1 SCOPE OF WORK

The opportunity of the contemporary effort is to develop an air purifier in research laboratory measure by introducing a model can reduce the air pollution as per the world health organisation permitted level by using a naturally occurring human hair and vetiver as a filter media. To reduce the air pollution causing due to the emission from various vehicles and burning of fossil fuel. In order to protect our environment to provide a clean air.

2.2 OBJECTIVES

1. To design and develop a compact, flexible, modular and low-cost air purifier employing a combination of porous plug and two filter media from natural resources.
2. To reduce the infusions of high levels of Smoke, Particulate Matter (PM), Total volatile organic compounds (VOC), Hydrocarbons (HCHO), Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), Carbon Monoxide (CO) and other air pollutants from the atmosphere.

3. METHODOLOGY

The invented air purifier model was developed based on PVC Pipes and fittings, including the 3 stage filtration process using a porous plate, hair media and Vetiver media (P. Thilagaraj, et al., 2014). To keep the Vetiver wet, channels for water inlet and outlet were also incorporated (V.P. Singh and Pawan Kumar 2017). The inlet air forced to enter the purifier unit using a blower at the inlet section with an air discharge rate of 0.5345 m³/s (Rojas-Sandoval J, 2020). At the interior, air comes first in contact with a porous plug which separates the large-sized impurities, dust and particulate matters (Adams, R. P. et al., 1998). Double layered porous plug screens of pore size 3 μm were used, which helps in the reduction of outlet air temperature (Mickovski, S. et al., 2005). According to the Joule Thompson effect, air passing from higher concentration to lower concentration tends the air to work itself, and the particles of air are colliding with each other while scattering through pores, then the temperature of the air is considerably reduced (Vannan Kandi Vijayan et al., 2015). If in case the temperature of the air is high, then the capture or settlement of air pollutants is difficult. So, reduction of air temperature is aimed to yield high removal of suspended particles (Zhe Wang, et al. 2016). The porous plates coupled in 5 places:

- One at Inlet Pipe (Pore size is 3 μm because of Double-layer to increase efficiency)
- One at entry and one at the exit of the first and second filter media (Pore size of 10 - 15 μm)

In the next stage, human hair mixed with vegetable oil adsorbs Particulate Matter (PM₁₀) (Van Boven F.E., et al., 2020). This idea was developed by observing the biological system of the human nose where human hairs wetted with mucus from the nose prevents the entry of dust and other particulate matters during inhalation of air (Aditya Roy et al. 2018). This principle is exceptionally essential in removing or capturing the suspended particles and other atmospheric pollutants of particle size more than 2.5 μm (example, PM_{2.5} and PM₁₀) (Review on air purifier Gowri Rajapandian et al. 2019). Human hair of size 50 - 100 μm and up to the length of 2 cm were used and mixed with Mahua oil, which could trap the suspended particles of size above 2.5 μm (Julie F. Hart Hindawi et al. 2011). Though any kind of vegetable oil with high viscosity can serve this purpose but, the cost of Mahua oil is low, and a very less volume of about 30 ml required for a complete cycle till getting blocked completely with pollutants (Yun Han Wang et al. 2015). Thus, the use of it abates pollution of the environment, and the proposal turns more cost-saving and environmentally concerned (Emily Cheek et al. 2021). These media kept covered with porous screens on both sides to restrict the movement of hair towards the outlet. If the pollution level is very high, then the hair filter media will get highly clogged, and replacement of media is required (Ashton Lim Suelee et al. 2017). Moreover, disposal is easy enough to be done in a pit because vegetable oil and human hair are completely naturally bio-degradable (Chomchalow, N. 2003).

The remaining PM_{2.5} is absorbed by water wet vetiver media with subsequent absorption of SO_x, NO_x and hydrocarbons (Danh, L. T., et al. 2009). Vetiver (*Chrysopogon Zizanioides*), locally known as khus-khus, is a native to Asia and mainly grows like a weed, possess the property of absorbing essential (nutrients) and non-essential (even pollutants) particles when they are wet because water is the primary requirement for Vetiver (Darajeh, Nel et al., 2014). Wetted Vetiver keeps enormous capability of absorbing gaseous particles like NO_x, SO_x, and HC with the efficient ability of absorption and adsorption of particle size even less than 2.5 μm like PM₁ (James L. Sublett 2011).

Producing a delightful smell, turns the environment fresher than the synthetic filters(Green R et al., 1999). A bunch of Vetiver of size 0.6 – 1.5 mm were used as the secondary filter media protected with the porous screens on either side(Hanssen,2004). By periodical wetting through the entry pipe of water, the Vetiver filter was kept wet three holes of 1cm diameter made to the water inlet on the top of the Vetiver filter(Macintosh D.L. et al., 2008). Entry of air restricted by the use of valves(Johnson L., et al. 2009). Cleaning of Vetiver media could be quickly done by cleaning and backwashing. Because of being a natural product, it is entirely bio-degradable and has no negative impacts on the environment(Fisk WJ et al. 2002). Porous plug screens also integrated to prevent the movement of Vetiver filter media,which also plays an influential role in reducing the temperature at each level(Sublett J.L., et al. 2010).

Figure 1. Symbolic representation of Air Purifier

Figure 2. Essential components of the air purifier:
(a) air blower, (b) porous plug, (c) human hair and (d) vetiver.

3.1 OVERALL WORKING PROCEDURE OF AIR PURIFIER

- Step. 1. Before running the air purifier, it is laid horizontally, and joints of both the filter media are required to be verified. Vetiver is wetted with water by inlet water pipes, and excess water is recycled.
- Step. 2. The blower is fixed at the inlet of pure. After checking all the parts and joints, the blower is started.
- Step. 3. The air stream is initially passed through the first porous plug (Double layer Screen), where their temperature gets slightly reduced, and some large-sized pollutants get trapped.
- Step. 4. Next, the air jet is passing through the primary filter media (Hair mixed with Mahua oil), where the particles of size above 2.5 μm get captured.
- Step. 5. Subsequently, the air is passed through the secondary membrane (Vetiver wetted with water). It absorbs and adsorbs the SPM of size less than 2.5 μm . It also captures NO_x , SO_x , HC and other organic compounds.
- Step. 6. After the cleaning and backwashing, Vetiver becomes reusable.
- Step. 7. When needed, both the media could be replaced based on the temperature conditions and pollution levels.

3.2 PERFORMANCE ANALYSIS

The level of pollution increases with an increase in the temperature. Thus, from morning to noon, the pollution level slightly increases (Stillerman A. et al. 2010). During the afternoon, high temperature remains along with high traffic and vehicles, which consequently elevates pollution. Now, for the air purifier unit, removal efficiency is calculated as:

$$\text{Pollutant Removal Efficiency} = \frac{\text{Initial Pollution Level} - \text{Final Pollution Level}}{\text{Initial Pollution Level}} \times 100\%$$

In fact, the pollutant removal efficiency exhibited by the air purifier unit for indoor observed to be more than 60% for PM₁, PM_{2.5} and PM₁₀(Pedroletti C et al. 2009).Particulate matter removal efficiency in the outdoor residential area found to be more than 75%, and for a heavily crowded region like bus-stand was found to be more than 65%(Morris RJ et al. 2006). Due to the Joule-Thomson effect, it observed that the temperature of exit air was about 5°C lesser than the incoming air(Hacker DW, et al., 2005).

3.3 COMPLETE SPECIFICATION

The accompanying drawings, which are included in and form a part of the specification, illustrate an incarnation of the present invention and, together with the description, serve to explain the principles of the invention(Sulser C et al. 2009). In the drawings:

1. Air blower
2. Hair Media (Human hair mixed with Mahua oil)
3. Vetiver media (Vetiver wetted with water)

Figure 3. Diagram with dimensions of the invention.

The proto-model of the Purifier developed is of the following specifications in Table 1.

Table 1. Specifications of High-Performance Air Purifier

S. No	Machine Parts	Purpose	Specifications
1	Air Pump (Blower)	The pump can be of any type that should suck enough air from the atmosphere and release it at one point.	Diameter of fan in blower = 10 cm Speed = 13000 rpm Frequency = 50 Hz Power = 230 V, 350 W AC

			Linear Velocity = 68.06 m/s Air Discharge = 0.5345 m³/s
2	Pipeline	PVC pipeline employed for the transportation of air from an air blower to an outlet.	Diameter = 50 mm Upto hair media chamber, length of pipe: 450 mm From hair media chamber to vetiver media chamber, length of pipe: 300 mm From vetiver media chamber to outlet, length of pipe: 300 mm
2	Porous Plate	The screens of pore size 3µm (Double-layered screen), used as the porous plate. The porous plates are used in 5 places	• Inlet Pipe Pore size is 3µm because of (Double-layer to increase efficiency) • Entry and exit of both membranes (Pore size of 10 - 15 µm)
3	Hair media chamber	The thick hair in the nostrils can prevent the entry of PM10, in the same way, Hair media made viscous using Mahua oil. It can trap the PM of size above 2.5 µm. These media are provided with screen membranes on both sides to prevent the movement of media.	Hair media chamber dimensions: 150 mm diameter and length 300 mm Hair size 50 - 100 µm and upto the length of 2 cm and mixed them with the mahua oil.
4	Vetiver Media	Vetiver is used in many fields to reduce the pollution from water and soil. In this innovative work, the Vetiver is used to reduce pollution from the air. The Vetiver having the property of absorbing essential (nutrients) and non-essential (even pollutants) particles when they are wet because water is the primary requirement for Vetiver. Wetted Vetiver having the property of absorbing gaseous pollutants like NOx, SOx, and HC. It will also absorb and adsorb the particles of size, even less than 2.5 µm (example, PM1). It has a very pleasant smell that makes the environment better many times than synthetic	Vetiver media chamber dimensions: 150 mm diameter and length 300 mm A bunch of Vetiver of size 0.6 – 1.5 mm dia and 120 – 150 mm in length are used as the secondary filter media.

		filters.	
5	Water Inlet and outlet	Continuous wetting of Vetiver could done through the water inlet. Hence, the inlet and outlet pipes provided for the entry and exit of water. Three holes of 1cm diameter are made for the water inlet on the top of the Vetiver media chamber.	Length- 1000 mm Diameter – 10 mm
6	Water Outlet	It was used to remove the excess water and also used to wash the Vetiver media.	Length- 1000 mm Diameter – 10 mm

4.EXPERIMENTATION

4.1 MEASUREMENT OF POLLUTION

Initially, the pollution level is measured by Air Quality Indicator at four places of Karur(Bernstein JA et al. 2005). They are,

- ❖ Karur Bus Stand
- ❖ Bypass Junction
- ❖ Vaiyapuri Nagar
- ❖ Near EB Office

The readings taken from 6 AM to 11 PM. During the measurement, the temperature varies as per the forecasted temperature(Batterman S, 2005).

Figure 0a Air Quality Meter Second Display

Figure 0b Air Quality Meter First Display

Table 2 Pollution Level - Karur Bus Stand (Jan 05, 2019)

Time	PM ₁ µg/m ³	PM _{2.5} µg/m ³	PM ₁₀ µg/m ³	HCHO mg/m ³	TVOC mg/m ³
6 AM – 7 AM	21	41	32	0.003	0.001
7 AM – 8 AM	28	47	35	0.001	0.003
8 AM - 9 AM	37	53	52	0.02	0.103
9 AM – 10 AM	52	61	71	0.031	0.221
10 AM -11 AM	60	79	88	0.05	0.353
11 AM – 12 PM	79	101	113	0.006	0.078
12 PM – 1 PM	39	54	58	0.003	0.031
1 PM – 2 PM	41	55	61	0.025	0.189
2 PM – 3 PM	34	45	50	0.004	0.036
3 PM – 4 PM	22	30	33	0.014	0.143
4 PM – 5 PM	78	101	113	0.19	0.195
5 PM – 6 PM	87	122	13	0.259	0.599
6 PM – 7 PM	92	138	27	0.221	0.762
7 PM – 8 PM	66	85	94	0.179	0.992
8 PM – 9 PM	243	321	359	0.01	0.117
9 PM – 10 PM	103	126	147	0.014	0.092
10 PM – 11 PM	66	88	98	0.009	0.088

Table 3 Pollution Level - Karur By-Pass Junction (Jan 06, 2019)

Time	PM ₁ µg/m ³	PM _{2.5} µg/m ³	PM ₁₀ µg/m ³	HCHO mg/m ³	TVOC mg/m ³
6 AM – 7 AM	19	28	21	0.004	0.002
7 AM – 8 AM	23	33	25	0.002	0.001
8 AM - 9 AM	49	52	59	0.009	0.097
9 AM – 10 AM	51	69	77	0.177	0.186
10 AM -11 AM	64	85	95	0.027	0.231
11 AM – 12 PM	42	56	60	0.012	0.115

12 PM – 1 PM	50	66	75	0.003	0.041
1 PM – 2 PM	28	38	42	0.039	0.278
2 PM – 3 PM	41	57	62	0.008	0.083
3 PM – 4 PM	24	32	35	0.01	0.1
4 PM – 5 PM	18	24	27	0.188	0.77
5 PM – 6 PM	22	30	33	0.016	0.164
6 PM – 7 PM	40	31	28	0.023	0.205
7 PM – 8 PM	41	55	61	0.234	0.667
8 PM – 9 PM	54	72	80	0.062	0.47
9 PM – 10 PM	62	68	73	0.022	0.16
10 PM – 11 PM	32	48	55	0.011	0.091

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Table 0 Pollution Level - Vaiyapuri Nagar (Feb 09, 2019)

Time	PM ₁ µg/m ³	PM _{2.5} µg/m ³	PM ₁₀ µg/m ³	HCHO mg/m ³	TVOC mg/m ³
6 AM – 7 AM	17	28	19	0.001	0.001
7 AM – 8 AM	28	27	39	0.001	0.007
8 AM - 9 AM	53	71	90	0.002	0.009
9 AM – 10 AM	48	65	72	0.009	0.11
10 AM -11 AM	42	56	62	0.007	0.153
11 AM – 12 PM	41	57	61	0.01	0.06
12 PM – 1 PM	38	50	57	0.006	0.063
1 PM – 2 PM	34	45	49	0.018	0.21
2 PM – 3 PM	36	48	53	0.019	0.198
3 PM – 4 PM	16	24	26	0.015	0.174
4 PM – 5 PM	19	27	28	0.016	0.23
5 PM – 6 PM	23	30	33	0.016	0.35
6 PM – 7 PM	32	40	43	0.021	0.43
7 PM – 8 PM	38	43	47	0.011	0.071
8 PM – 9 PM	49	54	48	0.009	0.091
9 PM – 10 PM	59	67	77	0.027	0.207
10 PM – 11 PM	37	41	39	0.011	0.12

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Table 5 Pollution Level - Near EB Office (Feb 10, 2019)

Time	PM ₁ µg/m ³	PM _{2.5} µg/m ³	PM ₁₀ µg/m ³	HCHO mg/m ³	TVOC mg/m ³
6 AM – 7 AM	21	38	16	0.007	0.051
7 AM – 8 AM	29	41	23	0.011	0.099
8 AM - 9 AM	38	50	53	0.024	0.171
9 AM – 10 AM	41	56	52	0.061	0.25
10 AM -11 AM	40	53	59	0.06	0.145
11 AM – 12 PM	44	59	64	0.03	0.114
12 PM – 1 PM	47	67	68	0.165	0.061
1 PM – 2 PM	27	36	40	0.112	0.042
2 PM – 3 PM	26	33	37	0.081	0.031
3 PM – 4 PM	26	35	38	0.07	0.049
4 PM – 5 PM	33	37	38	0.031	0.274
5 PM – 6 PM	18	24	27	0.23	2.96
6 PM – 7 PM	27	35	38	0.29	1.99
7 PM – 8 PM	33	37	39	0.281	1.53
8 PM – 9 PM	38	41	48	0.221	1.79

9 PM – 10 PM	45	49	54	0.209	1.83
10 PM – 11 PM	31	33	41	0.145	1.13

4.2 IMPACT ANALYSIS

- The measured values are clearly showing that the pollution will increase based on the increase in the temperature.
- From morning the temperature starts to increase hence the pollution level is slightly increasing.
- During noon even though the temperature is higher due to the less movement of vehicles, the pollution level is primarily moderate.
- After 5 PM, the temperature starts to fall, and the effect of high temperature remains increasing gradually till night. Simultaneously the traffic density is also increasing because of the peak hour, the pollution level is increasing as well.
- The following graphs will show the variations in the pollution level based on the time variation.
- In which the Time variations in the X-axis and pollution level in Y-axis ($\mu\text{g}/\text{m}^3$).

Figure 5 Graph showing pollution level - Karur Bus Stand

Figure 6 Graph showing pollution level - Karur By-Pass Junction

Figure 7 Graph showing pollution level - Vaiyapuri Nagar

Figure 8 Graph showing pollution level – Near EB Office

4.2 REDUCTION OF POLLUTION USING HIGH-PERFORMANCE AIR PURIFIER

After seeing the results of pollution measurement, it clearly shows that the air was highly polluted and purified(Myatt TA et al. 2008).We are experimentally going to run the prepared Air Purifier under various pollution level and Temperature range (Francis H et al. 2003). The pollution level checked near the outlet for outdoor testing.

The Purifier tested in the following three areas,

- ❖ Class Room of VSB Engineering College, Karur.
- ❖ Residential Area I in K. Paramathi, Karur.
- ❖ Residential Area II in K. Paramathi, Karur.

4.3 TESTING OF AIR PURIFIER IN CLASSROOM (INDOOR)

The classroom of the VSB Engineering College located on the first floor of Main Building II and 600m from NH 67. The temperature during testing is slightly pleasant and may in the range of 30°C to 33°C. The pollution level in this place is low to moderate(Gore RB et al. 2003). The dimensions of the classroom are 15Ft.X 20Ft.X 15Ft. The volume maybe about 4500 cubic feet. During the experimentation, all the windows and doors are closed.

The test conducted from 1:30 PM to 3 PM in the range of 15 minutes. The results tabulated from 0 to 90 minutes.

Table 6 Test results of Air Purifier - Class Room (Indoor)

Time (Min)	0	15	30	45	60	75	90
PM ₁ (µg/m ³)	41	33	31	25	22	18	17
PM _{2.5} (µg/m ³)	43	38	33	28	25	19	18
PM ₁₀ (µg/m ³)	49	39	37	30	23	19	19
HCHO (mg/m ³)	0.054	0.048	0.031	0.028	0.011	0.006	0.001
TVOC (mg/m ³)	0.326	0.291	0.276	0.211	0.112	0.041	0.013

4.4 TESTING OF AIR PURIFIER IN RESIDENTIAL AREA I (OUTDOOR)

A residential area of Annai Nagar, K. Paramathi village is selected for the first phase of outdoor testing(Yamamoto N et al. 2010). The place is just located 100 m from NH 67, and the test conducted during the evening. The temperature is low and may in the range of 29°C to 32°C. However, the effect of temperature was not reduced and may impact the pollution level. As we expected the pollution is high in this place.

The test conducted from 7:30 PM to 9:00 PM in the range of 15 minutes.

Table 7 Test results of Air Purifier - Residential Area I (Outdoor)

Time (Min)	0	15	30	45	60	75	90
PM ₁ (µg/m ³)	195	151	109	88	69	59	48
PM _{2.5} (µg/m ³)	258	207	173	151	98	86	53
PM ₁₀ (µg/m ³)	293	246	201	167	112	95	72
HCHO (mg/m ³)	0.023	0.019	0.015	0.011	0.008	0.006	0.006
TVOC (mg/m ³)	0.42	0.37	0.32	0.28	0.21	0.18	0.15

4.5 TESTING OF AIR PURIFIER IN RESIDENTIAL AREA II (OUTDOOR)

A residential area of K. Paramathi village selected for the first phase of outdoor testing. The place is just located 800 m from NH 67, and the test conducted during the evening. The temperature is high and may in the range of 34°C to 38°C. However, the natural feel was significant higher than the forecasted temperature, which may impact the pollution level, even though the place having a very low density of traffic. As we expected the pollution is high in this place.

The test conducted from 2:00 PM to 3:30 PM in the range of 15 minutes.

Table 8 Test results of Air Purifier - Residential Area II (Outdoor)

Time (Min)	0	15	30	45	60	75	90
PM ₁ (µg/m ³)	51	45	38	31	26	22	19
PM _{2.5} (µg/m ³)	55	47	41	34	27	24	18
PM ₁₀ (µg/m ³)	58	41	32	29	26	21	18
HCHO (mg/m ³)	0.009	0.007	0.004	0.004	0.002	0.001	0.001
TVOC (mg/m ³)	0.019	0.011	0.008	0.006	0.005	0.005	0.004

5 RESULT AND DISCUSSIONS

5.1 REMOVAL EFFICIENCY OF AIR PURIFIER

The efficiency is the ratio of pollution level before and after applying the Air Purifier.

$$\text{Removal Efficiency} = \frac{\text{Initial Pollution Level} - \text{Final Pollution Level}}{\text{Initial Pollution Level}} \times 100$$

5.2 CALCULATION OF EFFICIENCY OF AIR PURIFIER – INDOOR

$$\text{PM}_1 \text{ Removal Efficiency} = \frac{41-17}{41} \times 100 = 58.53\%$$

$$\text{PM}_{2.5} \text{ Removal Efficiency} = \frac{43-18}{43} \times 100 = 58.13\%$$

$$\text{PM}_{10} \text{ Removal Efficiency} = \frac{49-19}{49} \times 100 = 61.22\%$$

5.3 CALCULATION OF EFFICIENCY OF AIR PURIFIER – OUTDOOR I

$$\text{PM}_1 \text{ Removal Efficiency} = \frac{195-48}{195} \times 100 = 75.38\%$$

$$\text{PM}_{2.5} \text{ Removal Efficiency} = \frac{258-53}{258} \times 100 = 79.46\%$$

$$\text{PM}_{10} \text{ Removal Efficiency} = \frac{293-72}{293} \times 100 = 75.43\%$$

5.4 CALCULATION OF EFFICIENCY OF AIR PURIFIER – OUTDOOR II

$$\text{PM}_1 \text{ Removal Efficiency} = \frac{51-19}{51} \times 100 = 62.75\%$$

$$\text{PM}_{2.5} \text{ Removal Efficiency} = \frac{55-18}{55} \times 100 = 67.27\%$$

$$\text{PM}_{10} \text{ Removal Efficiency} = \frac{58-18}{58} \times 100 = 68.97\%$$

5.5 RESULT AND DISCUSSIONS

The test results are analysed and discussed with the following three graphs and the calculated removal efficiencies.

CLASS ROOM - INDOOR

Figure 9 Graph - Result analysis of Class Room (Indoor)

- ❖ This graph (figure 5.1) clearly shows that the Air Purifier has a removal efficiency of more than 58 % for removing all the three SPM when the pollution level is low in range.
- ❖ The air purifier is operated for 90 minutes continuously.
- ❖ In which the PM_{10} removal is high as more than 61%.

5.6 RESIDENTIAL AREA I (OUTDOOR)

- ❖ Figure 5.2 showing the graph of the test result of Air Purifier tested in residential area 1 with a high level of pollution.
- ❖ It shows the overall removal efficiency of more than 75% after continuous running for 90 minutes.
- ❖ It removed the $\text{PM}_{2.5}$ as high as more than 79%.

Figure 10 Graph - Result analysis of Residential area I (Outdoor)

5.7 RESIDENTIAL AREA II (OUTDOOR)

- ❖ Figure 5.3 of the graph showing the test result of air purifier tested in residential area 2 with a moderate level of pollution.
- ❖ It shows the overall removal efficiencies of more than 62% after continuous running for 90 minutes.
- ❖ It removed the PM_{10} as high as more than 68 %.

Figure 11 Graph - Result analysis of Residential area II (Outdoor)

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5.8 OVERALL ANALYSIS OF REMOVAL EFFICIENCY

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Figure 12 Removal efficiency result upto 90 minutes

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Figure 5.4 shows that, the High-Performance air purifier successfully removes almost 60 % of the SPM after a continuous run of 90 minutes.

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The pollution level and the temperature variations also having a vital role in the removal efficiency.

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6.CONCLUSIONS

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After elaborate study, we can conclude this project with two parts. They are,

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- Solution for Air Pollution
- Future Implementation

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6.1 SOLUTION FOR AIR POLLUTION

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- After completing of the tests on various pollution levels and temperature, this model can reduce the pollution level to the WHO permitted level and even less than those standards.
- World Health Organisation provided the standards for the PM_{2.5} and PM₁₀ as below:

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PM_{2.5}: 10 µg/m³ – annual mean & 25 µg/m³ – 24 hour mean

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PM₁₀: 20 µg/m³ – annual mean & 50 µg/m³ – 24 hour mean.

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- But this purifier with hair and Vetiver as filter media reduces almost 60% of the pollution causing SPM from the air within 90 minutes. Air temperature also can reduce about 40 to 50°C.
- It observed that whenever pollution levels are high-performance also high, which is nearly 90%. Hence this purifier is much suitable for highly polluted areas.
- If large membranes provided, then the efficiency will be increased up to 90%.
- It is possible to provide large membranes since both filter media are bio-degradable. So, it does not create any impacts on the environment in the name of environmental development.
- It will reduce the air pollution and also reduce the severe diseases like cancer and asthma.

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6.2 FUTURE IMPLEMENTATION

As it effectively reduce the air pollution in a manner without having any side effects to the environment as well as humanely, it can be implemented in public places and residential places.

By using quiet motors, we can adopt this purifier in any kind of environment.

Air pollution due to the burning of fossil fuels will become higher due to the increase in the rate of vehicles sale in India. It will lead to an increase in CO₂ concentration in the atmosphere.

Hence, this is the one way to reduce the SPM released from the burning of fossil fuels and many sources.

Now, India has lost many cities which, are their living suitability due to the increase in air pollution.

Example: Delhi, Mumbai and some cities of Chennai.

We recommend this purifier in an enlarged manner to reduce the air pollution and bring back the cities to their previous status without air pollution.

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316 **Ethical approval**-This content is fully prepared by our own.

317 **Consent to participate**-We are consenting to participate.

318 **Consent to publish**-We are consenting to publish.

319 **Author's Contribution –**

320 *Anand Kumar Varma S.* conducted the research work for the full experimental recordings and completion of the full
321 work with the entire correction.

322
323 *Suvalakshmi A.* works for the entire manuscript preparation.
324

325 *Manjula.K.R* making model, revised the entire manuscript and verified the data .

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328 **Availability of data and materials-**

329 We measured the pollution level from different outdoor places .

- 330 ❖ Bypass Junction
331 ❖ Vaipayuri Nagar
332 ❖ Near EB Office
333 ❖ Karur Bus Stand
334

335 We measured the pollution level from different indoor places

- 336
337 ❖ The classroom of the VSB Engineering College located on the first floor of Main Building.
338 ❖ A residential area of Annai Nagar, K. Paramathi village is selected for the first phase of outdoor testing.
339 ❖ A residential area of K. Paramathi village selected for the first phase of outdoor testing.

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