Design and Development of Advanced Air Purifier Facial Mask

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Abstract

Nowadays air pollution is the leading concern among the people. To be safe from the polluted air, using the available general mask is not sufficient to avoid severe health hazards. If modern technology can be embedded into a mask with every layer of protection from the air pollution then it will be a safer mask to use. This paper is about to develop a more advanced mask with a different layer of protection from dust, bacteria and hazardous elements of the air in low cost with wirelessly airflow control system. The product ensures 94% purification of air with its embedded technology. Before developing the mask a survey has been done and the product is designed on the basis of customer requirement. Materials of the product are selected through the relative performance index of the key features. This will be made at the lightweight so that users will feel comfortable to use. The Product is targeted to the customers' e.g. Factory workers, Medical Patient, General People. The product is low power consumption and can be charged fast. It can be run about 8 hours with fully charged.

Keywords: Mask, Air purifier, Nano filter, Wireless, Air Pump

1 Introduction

It is estimated that outdoor air pollution causes 4.2 million excess deaths worldwide each year. There is a good reason to worry about Air Quality at the Environmental Performance Index for Air Quality. According to the World Health Organization, 91% of the world's population lives in places where air quality exceeds WHO guideline limits. The cost of a polluted environment: 1.7 million child deaths a year, says WHO. Air pollution acts as a silent killer.9 out of 10 people worldwide breathe polluted air.

Air pollution levels increasing in many of the world's underdeveloped and developing cities. Most of the air pollution is happening to the industrial area and it is now unstoppable. And it is also uncontrollable to purify the air of the whole industry. Thus, the workers of the industry are facing very severe health problems because of air pollution. The musk they wear barely remove the hazardous and finer particles which cause very bad effects on their health. Most of the factory workers don't wear a mask due to their loss of lung capacity, bronchitis, asthma etc. People are facing lack of sleep and are getting tired because of breathing the polluted air more and more.

Advanced Air Purifier Facial Mask is designed to provide 94% purified air. This project idea also includes bacteria killing by UV light protection. This mask can remove the fine particles of below 0.3 microns and Nanoparticles easily and efficiently. Normal masks can't provide all the protections. In this product, anyone the smokes, fumes, odors, and chemicals are removed through the carbon filter. Then the HEPA filter is generally used to separate the dust, particles larger than 0.3 microns etc. A polarizer is used for the advanced bacteria protection and separation of the particles from the air and with Nano filter removes the other particles of Nano level. The air pump is used in this product for a better-controlled supply of air. It gives wireless connectivity up to 10 meters.

2 Literature Review

Air purifiers with Second Hand Smoke education is a feasible intervention in homes of women and infants stated by (Rice et. al. 2018). After application of air purifier, what kind of air pollution level inside the room can be maintained

with the corresponding outdoor pollution condition calculated by (Xu 2019). An in-situ thermally regenerated air purifier (TRAP) which self-regenerates as needed, has four working modes: cleaning mode, regeneration mode, exhaust mode, and outdoor air in-take mode, all of which are operated by valve switching developed by (Xiao et. al. 2018). A facial mask assembly for covering at least the nose and nares of a patient's face and compensating for any unequal forces that may be generated in the straps holding the mask on the patient's face, invented by (Ogden DR et. al. 1997). A respiratory mask assembly includes a respiratory mask including a mask shell and a mask cushion, a forehead support adjustably coupled to the mask, and an angular adjustment member discovered by (Kwok PR et. al. 2017). The efficacy of a unique transparent face mask containing silicone sheets on the esthetic outcome of postsurgical facial flaps is assessed, described by (Kant et. al. 2018). A semi-automatic modeling system and prototype fabrication are proposed to help the infection control practitioner in the process of the respirator design for all healthcare worker without CAD experience done by (Li et. al. 2018). Occupational IgE-mediated allergic respiratory disease was severe and could be controlled only with omalizumab (decrease in symptoms, improvement in respiratory auscultation and spirometry), in addition to reducing exposure by use of mask described by (Torrijos et. al. 2018).

3 System Architect

In the air there are different types of molecules, bacteria, viruses etc. and normal filters can't remove the bacteria from the air. The popular method of doing this is ionizer. The ionizer helps to remove the particles from the air as small as 0.01 microns. The carbon filters help to remove the odor, smokes, fumes, and chemicals. The HEPA filters help to remove the particle greater than 0.3 microns and also dust, pollen, and microorganisms. The Nano filters finally remove the particles Nano in size. The airflow can be controlled by the smartphone by controlling the compressor. Arduino will be included inside the design. Arduino Nano is a low power and highly efficient microcontroller board based on the ATmega328P.It has a built-in ADC and USART communication feature. In this system, for analog to digital conversion and serial transmission of the pulse sensor data Arduino Nano is used.

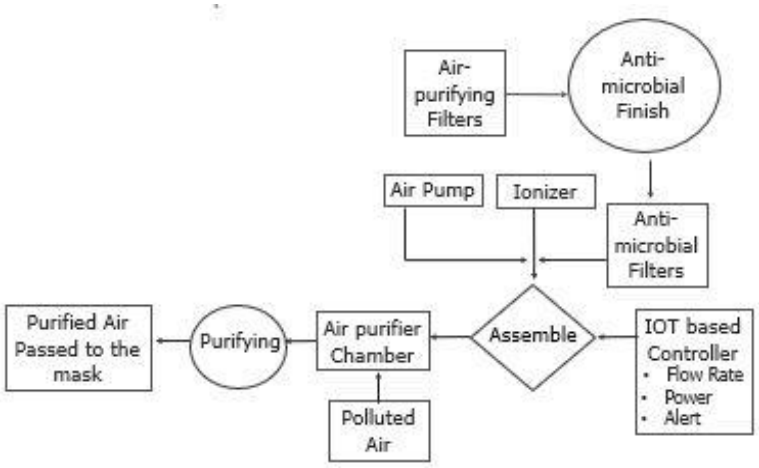

Figure 1. Flow chart for Advanced Air Purifier Facial mask

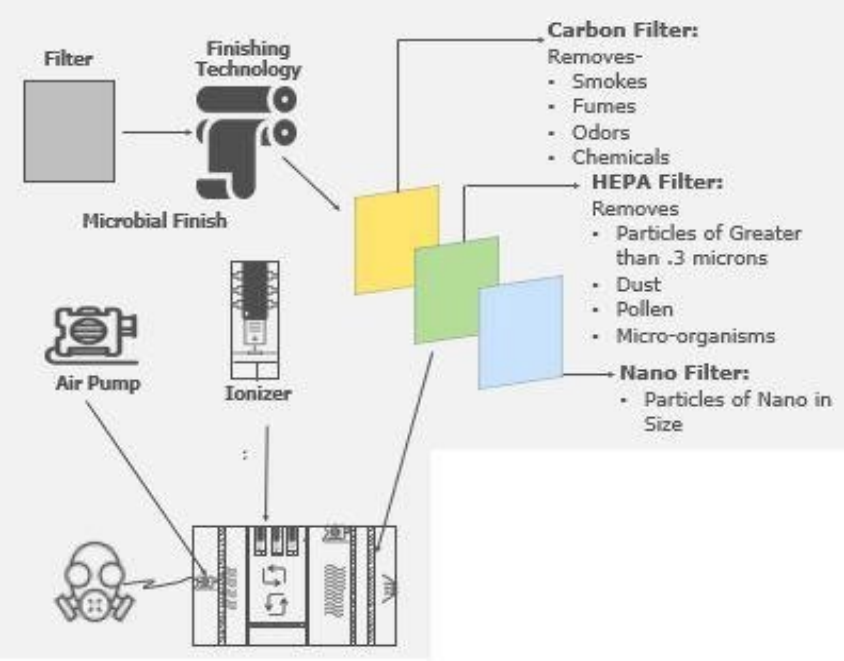

Figure 2. System Architect of wirelessly controlled Air Purifier Facial mask

4 Proposed Methodology:

4.1 Power supply:

In this system, two 3.7V disposable Lithium battery is used for making it portable. For the safety and short circuit protection, a voltage regulator LM7805 is used. In this system, all equipment get the power from the battery. It is done to stay away from power line interference (50Hz) and other noise interference. To recharge the power system there is added a charging IC and a protection circuit TP4056. In figure 5 dual power supply for the system is shown.

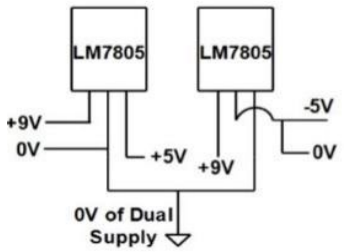

Figure 3. Designed Power Supply for the system

4.2 Serial Transmission using Arduino Nano:

Arduino Nano board contains an 8 channel 10-bit analog to digital converter. It returns a linear and analog from 0 to 1023 corresponding to 0V and +5V respectively. For serial transmission of baud rate is taken as 9600 bps and sampling rate of 320 samples per second is applied. Arduino Nano has a built-in USART communication feature which allow USART transmission and reception via digital pins 1 and 0. For serial communication pin 1 and pin 0 of Arduino Uno needs to connect with Bluetooth modules Rx and Tx and figure 6 shows the connections. A Bluetooth module HC-05 establishes signal transmission between Arduino UNO and Android phone.

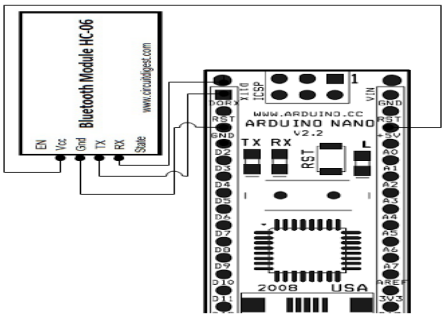

Figure 4. Connection between Arduino Nano and Bluetooth Module HC-06

4.3 Software implementation:

The software is implemented in two sections. One is device section and other is android application section. The device section is used to drive hardware and the application layer is for the user to control the air flow rate through android apps. To programme, the microcontroller integrated development module provided by the Arduino platform will be used. An Android application and a software for the laptop is developed by processing which is an open source programming language and Arduino IDE. To develop the system there will be used Processing IDE of version 2.20. For receiving serial data from the Bluetooth module, BtSerial library will be used. For developing the software used in laptop serial library of processing was used to receive the data from Arduino Nano.

4.4 Activated Carbon Filter:

Carbon filters have application as air filters and are used to remove the gases from the air and also the odor. But applying the activated carbon filter provides the ability to remove volatile organic compounds (VOCs), odor and other gaseous pollutants. Carbon filters use ad-sorption Method for removing the gaseous particles. By the adsorption, the gaseous pollutants stick to the outside of the carbon. One gram of activated carbon can have hundreds of square meters of internal surface area.

4.5 HEPA filter and Nano Filter:

HEPA filters remove the smallest size of particles from the air. Average human hair is about 100 microns and HEPA filter can remove up to .3 microns' filter will be used after the Activated Carbon Filter is used. Then the Nano filter will be used to separate the finer particles from the air near to .001 micron. Nano filters will be given antimicrobial finish for better filtration and protection against bacteria.

4.6 Ionizer Unit:

This Ionizer unit provides the advance protection against the bacteria and other finer particles that has previously been passed through the filters. This ionizer helps to trap the finer particles in the air. It works by applying the high voltage to the air through the needles which is in-built. The air is become negatively ionized and it attracts the positively charged smoke, finer particles, dust etc. Thus the particles from the air are dropped down and air is again filtered.

4.7 Air Pump:

Air flow through the filters get slower after one by one filtration. For increasing the air flow air pump is used. There are used two air pumps in the design for better performance. Speed of the two air pumps are equal so that air can flow simultaneously. An adult inhales and exhales about 7-8 liters/min. The air pumps are able to supply air 5-15 liters/min. The power consumption is very little of the pump and the noise is below 15db.

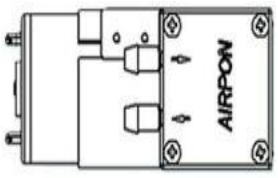

Figure 5. Air Pump used in Advanced Air Purifier Facial Mask

4.8 Material Selection:

Customer requirement is very important while designing a product. During designing we have to think about different technical features. To make a good and usable product we need to make connection between customer need and technical features. To determine which features can satisfy customer demands most by Quality Function Deployment (QFD) shown in table 1. A survey is performed and picked 6 customer requirements from the questions. They (Purification capability, Comfort, Applicable environments, Light Weight, Low Cost & Low Power Consumption) are ranked 1 to 6 according to importance. To fulfill the customer requirement and technical features of materials should be selected according to their technical properties. Five Technical properties (Filters, Ionizer, Air-pump, Microcontroller, and Battery) are rated against customer requirements. With a strong relationship between them scored 10 points, medium relationship stands 5 points and poor relationship scored 2 points. Weighted total scores and percentage scores are considered for ranking the technical properties. To find the material that fits best to the product for the better performance we used the digital logic method for determining the relative importance of each technical properties and gave them according weights shown in table 2.

Table 1. QFD shows the relation between customer requirements and technical features

Strong Relationship ● 10 points
Medium Relationship ○ 5 points
Poor Relationship ▲ 2 points

			Technical requirements					
		Rating	Filters	Ionizer	Air Pump	Microcontroller	Battery	Our Product
Customer Requirements	Purified Air	6	●	●				G
	Comfort	5	○	○	●	▲		F
	All Environment	4	○					G
	Light weight	3			○	○	▲	F
	Low Cost	2	●	●	●		○	F
	Low Power Consumption	1		▲	○	●	●	G
	Score		125	107	90	35	26	
	Percentage score		33	28	23	9	7	

Table 2. Determining the relative importance of goals using digital logic method

Number of positive decisions: n(n-1)/2=10

Selection criteria	1	2	3	4	5	6	7	8	9	10	Positive Decisions	Relative emphasis co-efficient
Capacity	0	1	0	0							1	0.1
Porosity	1				1	0	0				2	0.2
Compatibility		0			0			0	1		1	0.1
Flow Rate			1			1		1		0	3	0.3
Efficiency				1			1		0	1	3	0.3
	Total Number of Positive Decisions										10	

Performance index of HEPA Air Filter and ULPA Air Filter have been calculated and we have seen that performance index of HEPA Air filter is better and so we choose to use HEPA Air Filter.

Table 3. Calculation of performance index of HEPA Air Filter and ULPA Air Filter

Selection Criteria	Weighted Factor	HEPA Air Filter		ULPA Air Filter	
		Scaled Property	Weighted Score	Scaled Property	Weighted Score
Capacity	0.1	60	6	50	5
Porosity	0.2	75	15	70	14
Compatibility	0.1	60	6	70	7
Flow Rate	0.3	85	25.5	85	25.5
Efficiency	0.3	90	27	90	27
Material Performance Index			=79.5		=78.5

Performance index of Carbon Air Filter and Standard Air Filter have been calculated and we have seen that performance index of Carbon Air filter is better and so we choose to use Carbon Air Filter.

Table 4. Calculation of performance index of Carbon Air Filter and Standard Air Filter

Selection Criteria	Weighted Factor	Carbon Air Filter		Standard Air Filter	
		Scaled Property	Weighted Score	Scaled Property	Weighted Score
Capacity	0.1	55	5.5	50	5
Porosity	0.2	70	14	60	12
Compatibility	0.1	80	8	60	6
Flow Rate	0.3	80	24	50	15
Efficiency	0.3	90	27	50	15
Material Performance Index			=78.5		=53

Performance index of Ultraviolet Filtration and Ionizer Filtration have been calculated and we have seen that performance index of Ionizer Filtration is better and so we choose to use Ionizer Filtration.

Table 5. Calculation of performance index of Ultraviolet Filtration and Ionizer Filtration

Selection Criteria	Weighted Factor	Ultraviolet Filtration		Ionizer Filtration	
		Scaled Property	Weighted Score	Scaled Property	Weighted Score
Capacity	0.1	70	7	60	6
Porosity	0.2	0	0	0	0
Compatibility	0.1	80	8	70	7
Flow Rate	0.3	80	24	80	24
Efficiency	0.3	70	21	90	27
Material Performance Index			=60		=64

Cost Analysis:

Table 6. The list of the component used for this system

Component Name	**Quantity**	**Unit Price (USD)**	**Total Cost (USD)**
Arduino NANO	1	1.875	1.875
HC-05	1	2.25	2.25
Resistor	6	0.01	0.06
Capacitor	2	0.02	0.04
9V battery	1	1.10	1.10
TP4056	1	0.50	0.50
Ionizer	2	4.80	9.60
Filter	3	0.80	2.40
Air Pump	2	02	04
Total cost of the system			21.825

5 Conclusion:

The main aim of this research is designing and building a low cost, wirelessly controlled advanced air purifying facial mask. This system is both wireless and manually controlled. As the system is battery powered and low noise making air pump is used, so the noise interference is reduced and subject safety is ensured. The cost of the system is USD 21.825 which is ideal for under developed and developed countries. The component used for this system consumes very low power and it takes maximum current of 55 mA. It is capable of running about 8hrs by one full charge. It can be more cost efficient by further development in future.

6 Reference:

Li J, Tanaka H, Miyagawa S. Applying the Programmable Modeling Tool to Support the Hospital Infection Control Staff in Customizing the Filtering Face-Piece Respirators for Health Care Worker. *International Conference on Applied Human Factors and Ergonomics* 2018 Jul 21 (pp. 270-279). Springer, Cham.

Kant SB, Ferdinandus PI, Van den Kerckhove E, Colla C, Van der Hulst RR, de Grzymala AA, Tuinder SM. A new treatment for reliable functional and esthetic outcome after local facial flap reconstruction: a transparent polycarbonate facial mask with silicone sheeting. *European journal of plastic surgery*. 2017 Oct 1;40(5):407-16.

Kwok PR, Gunaratnam MK, Lithgow PD, Harrison JP, Liston JL, Matchett RS, Styles RE, inventors; ResMed Ltd, assignee. Forehead support for facial mask. *United States patent US* 9,592,359. 2017 Mar 14.

Ogden DR, Abeyta JA, Keefe GD, inventors; Respironics Inc, assignee. Respiratory facial mask. *United States patent* US 5,662,101. 1997 Sep 2.

Rice JL, Brigham E, Dineen R, Muqueeth S, O'keefe G, Regenold S, Koehler K, Rule A, McCormack M, Hansel NN, Diette GB. The feasibility of an air purifier and secondhand smoke education intervention in homes of inner city pregnant women and infants living with a smoker. *Environmental research*. 2018 Jan 1; 160:524-30.

Torrijos EG, Rodriguez CG, Pérez BV, Bartolomé B, Barragan MP, Rodriguez RG. Occupational allergic respiratory disease (rino-conjunctivitis and asthma) in a cheese factory worker. *The Journal of Allergy and Clinical Immunology: In Practice*. 2018 Jan 13.

Xiao R, Mo J, Zhang Y, Gao D. An in-situ thermally regenerated air purifier for indoor formaldehyde removal. *Indoor air*. 2018 Mar; 28(2):266-75.

Xu Z. Calculation on Cleaning Capability of Air Purifier [1]. InAir Purifier 2019 (pp. 101-127). *Springer, Singapore*.

Biography:

Md Mamunur Rashid is an Assistant Professor in Industrial and Production Engineering at Bangladesh University of Textiles (BUTEX). He received his B.Sc. degree in Industrial and Production Engineering from Bangladesh University of Engineering and Technology (BUET), in 2013. He acted as a corporate professional in both Textile and Garments units of DBL Group to apply Industrial Engineering tools and techniques prior to starting his academic career as a Lecturer at BUTEX in 2015. He has been involved in different research projects in the area of multidisciplinary optimization, artificial intelligence application, supply chain management, operations scheduling, inventory management, and lean manufacturing. Mr Rashid is a life member of BSTQM.

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