Improving Indoor Air Quality with Water-based Air Filtration System

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Abstract- **This paper explains the design and development of a water-based air filter system for recycling and cleaning the air indoors; particularly in houses, classrooms and offices. The device is developed as the concerns for indoor air pollution has arisen and to introduce an economic and environmental friendly system for filtering air. The water-based air filter system includes a support base which provides portability to it, and also includes a tank being at least partially-filled with water and having an inlet through wall where polluted air is drawn in by an exhaust fan into the water in the tank and also having an outlet holes at the top to let out filtered air into the surroundings. Water is introduced in this design as it is the cheapest easiest source of cleaning element to find. It also helps in reducing the use of cartridge filter and material saving.**

Keywords- **Air filter, pollution, particles, indoor, air-quality**

I. INTRODUCTION

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants.[7]

Particles are very small solid or liquid substances that are light enough to float suspended in air. Air borne particles include smoke, smog, bacteria, household dust, pet danders, mold spores debris and pollen. These particles range in size between 0.3 to 100 microns. Considering that the average diameter of human hair is 50 microns, these particles are so small that most pas right through ordinary filters right back into home. They are composed of diverse materials including inorganic and organic compounds and dormant and living organisms. The primary concern from a health standpoint are: 1) small, invisible respirable-size particles, with a higher probability of penetrating deep into the lungs, where they may stay a long time and may cause acute or chronic effects, and 2) larger particles, such as some molds, pollen, animal dander, and house dust allergens, which do not penetrate as deeply, but may cause an allergic response. Health effects from exposure to respirable-size particles in the air depend on the types and concentrations of particles present, the frequency and duration of exposure, and individual sensitivity. Health effects can range from irritation of the eyes and/or respiratory tissues to more serious effects, such as cancer and decreased lung function. Biological particles, such as animal and insect allergens, viruses, bacteria, and molds, can cause allergic reactions, infectious diseases, and/or can produce toxic products which may be released into the air.[1,3, 4,7]

The U.S. Environmental Protection Agency have identified that indoor air pollution as one of the top five environmental risks to public health. The Agency defines indoor air pollution as chemical, physical or biological contaminants in the breathable air inside a habitable structure or conveyance, such as in homes, schools, offices, and vehicles. Sources of indoor air pollution include natural sources, building materials, products, and occupant activities. Health effects from indoor air pollution range from immediate to long-term, and treatable to severely debilitating or fatal.

The purpose of water-based air filtration system was initially to overcome the problems faced by the community. While it helps to filter the indoor air from particles and unpleasant odors, the cleaning element which water is economic and environmental friendly as not chemical used thus it is safer to dispose the water into the waste water system. The system includes a support base which provides portability to it, and also includes a tank being at least partially-filled with water and having an inlet through wall where polluted air is drawn in by an exhaust fan into the water in the tank and also having an outlet holes at the top to let out filtered air into the surroundings. Water is introduced in this design as it is the cheapest easiest source of cleaning element to find. It also helps in reducing the use of cartridge filter and material saving.

When entering the tank,the particles in the smoke will trapped in water by the turbulence produced by the pump. Water is circulated to permit more particles to be trapped thus provide filtered that will go through the roof. A sponge filter similar to thoseused in fish aquarium will be immersed into the water to caught the smoke particles trapped by water. When the filtered air went through the roof section, again it will be filtered by odor repellent agents, which we used coal and fragrance beads. The air will be released into the surrouding again through outlets which is mounted at the top of the roof.

The system is capable of filtering air particles as small as 10 microns, which is the average size of molds, pollen, animal dander, and house dust allergen. This will help in reducing the risk of the particles from entering the respiratory system. Besides worsening the cases of asthma and allergies, these particles particularly cigarette and coal smoke add acidity to

the air. This is proved by experiment which will be discussed further in this paper.

II. METHODOLOGY

The first step of implementing the project is information searching . This step comprises into two main sources, which is from research and consumer (questionnaires). In this method we need to gather all the information that they can use to start the project and get the earliest idea. From the information that has been gathered, the consumer and market needs can know for the reference.

Research

Research has been made on how effective are air cleaners in reducing pollutant concentrations in indoor air. The effectiveness of air cleaners in removing pollutants from the air depends on both the efficiency of the device itself (e.g., the percentage of the pollutant removed as it goes through the device) and the amount of air handled by the device. For example, a filter may remove 99% of the pollutant in the air that passes through it, but if the air flow rate is only 10 cubic feet per minute (cfm), it will take a long time to process the air in a typical room of 1000 cubic feet.

Although there is no universally accepted method for comparing air-cleaning devices, several investigators of portable air-cleaning units have expressed their results as a "clean air delivery rate" or CADR. The CADR is the product of the unit efficiency and the air flow rate, and is a measure of the number of cfm of air it cleans of a specific material. For example, if an air cleaner has a CADR of 250 for smoke particles, it may reduce smoke particle levels to the same concentration as would be achieved by adding 250 cubic feet of clean (ventilation) air each minute.

Dasgupta and collegues have used different approach in measuring the air pollution by measuring the Total Suspended Solids (TSS) to the water exposed to the polluted air [7]. During the experiments and testing to prove the product's efficiency, we aprroached the same methods of testing and tested the pH of filtering water as well.

Questionnaires

A questionnaire form consists of a series of questions for the purpose of gathering information from respondents was distributed for three main target group which were observed to spent their time frequently indoor. From the gathered information, consumer and market needs can be defined. The questionnaires were distributed among college residents, office workers and residents of housing areas of Kg Wai, Kuala Perlis. 200 questionnaires were distributed and 88% of the questionnaires was responded. Figure 1 depicts the percentage of respondents from the survey.

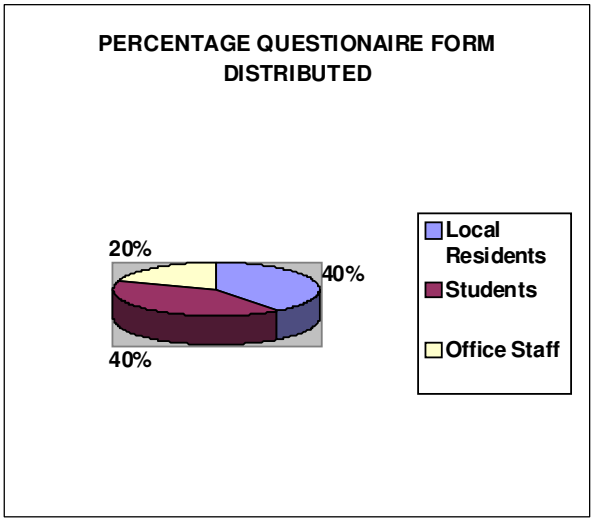

Fig.1. Percentage of questionnaires distributed to the respondents

From the survey 40% of the respondents supported the importance of having an air filtration system in their homes. 55% of the respondents agreed that indoor air is not healthy enough and nearly 70% of the respondents did not practice the healthy way of maintaining indoor air clean.

From the responses we perform the activity analysis to learn how the customer will use and retire the product. The activity analysis also is important to examine the relationship between customer and the product. An analysis of the activity will lead to the sub functions that need to be fulfilled in the final design i.e. overall product function. In Table 1 we have developed the activity analysis list for our reference in designing the concepts for our project.

TABLE I
ACTIVITY ANALYSIS LIST

Use	Setup	1. Assemble the tank with roof cover 2. Place fragrance or coal to filter odor 3. Fill in water 4. Place pump into water 5. Plug in 6. Place on support base trolley
	Daily use	7. Switch on the power supply 8. Filter indoor air 9. Transfer air filter to any areas required air filtering
	Replace cleaning fluid	10. Remove the roof cover 11. Remove water pump 12. Pour water into sink and replace with clean water
	Replace	13. Disassemble exhaust fan

	components	or pump if malfunctioning 14 Replace with new fan or pump
Retire	Dispose of air filter	14. Throw out the air filter and auxiliaries.

Concept Development

The next step is concept development and it divide into two main activity that is generated of the concept and concept selection. Before get the final concept, a few concepts must to generate to get more choice to get the good concept of the design using Morphological Matrix. This system covered to the frame machine, mechanical component and electrical. From the few concepts, screening needed to ensure the best concept must be chosen using Pugh Method. The final process this is the selection for suitable type of material and equipment in order to supply this project. There are also factors which were considered during function determination of the system:

1. The potential effectiveness of the device under the conditions it will be used.
2. The need for routine maintenance, including cleaning and replacement of filters and parts
3. The estimated capital and maintenance cost.
4. The installation requirements (e.g., power, access).
5. The inability of air cleaners designed for particle removal to control gases and some odors, such as those from tobacco smoke.
6. The noise level at the air flow rates that will be used.
7. The mass of the particles entering the device.
8. The characteristics of the particles (e.g., their size).
9. The degradation rate of the efficiency of the capture mechanism caused by loading.
10. Whether some of the air entering the unit bypasses the internal capture mechanism.
11. How well the air leaving the device is mixed with air in the room before reentering the device.

From the list we have summarized that there are seven main parts that need to be designed Table 1 show the concept selection method used. Concept 1 is chosen to be the combination to fabricate the prototype.

TABLE II
CONCEPTS GENERATION TO BE EVALUATED BY PUGH'S METHOD

Selection criteria (element)	Concept		
	1	2	3
Fan	Ventilating fan (size 292 x292)	CPU fan (70x15 mm)	Vacuum type
Pump	Aqua-Bee Aquarium Pump	Undersea Encounter Aquarium Pump Kit	New Two Piece Magnetic Aquarium Pump
Roof	plywood	Perspex (arcrylic)	Aluminum
Tank	Perspex	plywood	Aluminum
Cartridge	Slot cartridge	Water filter	W filters
Power supply	240V	13V (battery)	10V
Trolley	Plywood	Perspex	Aluminum

Modelling the Design

Using 3D Computer Aided Design Software, a model was developed to get the final view of the product. The final model includes all part of the air filtering system which consists of the main tank, fan, roof and trolley. The size of the tank is 400 millimeters in width, 500 millimeters in length and 582 millimeters in height. Water for filtering fluid can be filled up to 0.6 cubic meters which is estimated to quicken the polluted air filtering indoor. Fabrication of the prototype is carried out to prepare for the experiments and to prove whether the objective is achieved. Figure 2 shows the final model of the product in three dimensional. In Figure 3, the exploded view shows the assembly relations between the parts.

Fig. 2. Three dimensional model of water-based indoor air filtering system

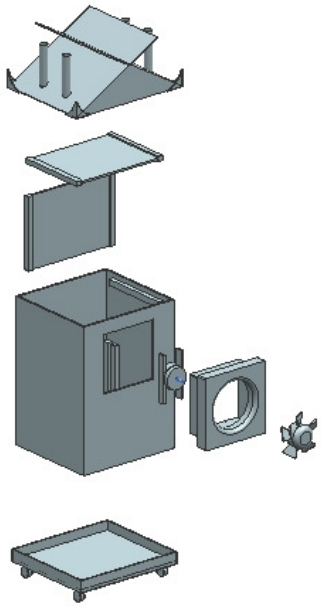

Fig 3 : Exploded model of air filtering system to show the assembly relations between the parts.

Experimental Procedure

Experiments were carried out at Air Pollution laboratory, School of Environmental Engineering, Universiti Malaysia Perlis. First permission to use the facilities at the laboratory was asked from the Dean. Experimental procedures were then developed to observe the efficiency of the product.

The experiments are done in a closed room with the length of 12 ft, width 10 ft and height of 15 ft. Papers and coal were burned in a container to produce smoke into the air. There are no form of air inlet and outlet to the room. We assumed that there are no influence of outdoor air in this experiment and all the smoke produced by the paper and coal burning activity will be filtered thoroughly by the system.

A day before conducting experiment with the system, we did some observation on how long will the smoke clear in the closed room without any form of ventilation. Papers were leaved on the floor to get the dust from the smoke. There are still traces of smoke in the air when we came back the next day and it leaves smoke residues on the walls and floor. Before the testing began we wiped the floor and walls to clear away the dust.

The first experiment is to measure the changes of water pH when the water tank is polluted by the drawn smoke using pH meter. Sample of water from the tank was taken for testing at the initial stage before testing began and during the testing with the interval time of 10 minutes. Reverse-osmosis water is used in this experiment to produce reliable results.

The next experiment is to measure the water pollution is measured by discharge of Total Suspended Solids (TSS) from the smoke produced by the paper and coal burning using UV Spectrophotometer. Sample of water from the tank was taken for testing at the initial stage (before smoke is produced) and during the testing with the interval time of 10 minutes of each sample. The polluted water was blended at high speed to ensure the particles dissolve evenly in the water before testing. The time taken for the testing is one hour when the smoke is practically cleared in the room.

III RESULTS AND DISCUSSION

With the help of the motor pump to circulate the air, it was observed that the air filtering process was efficient as the smoke began to clear wihin an hour. Compared to our observation before, the smoke took nearly a day to clear from the room without any form of ventilation. Compared to the day before, there are less traces of smoke residues on the wall and floor. We observed the differences by comparing the dirt on the papers from the day before and after the experiment using the air filtering system.

From the experiment it is observed that the acidity of water increased propotional to the filtering time. The initial pH of water before running the system was 7.1. The pH reading gradually decreased as more polluted air is drawn into the water. The decrement of pH reading stopped at 50 minutes interval, where the smoke beginning to clear in the room.

The reading of TSS also increased proportionally to the time, proving that the quantity of smoke particles trapped by water increased by the time. Figure 4 and 5 show the pH reading and TSS versus time of the experiment.

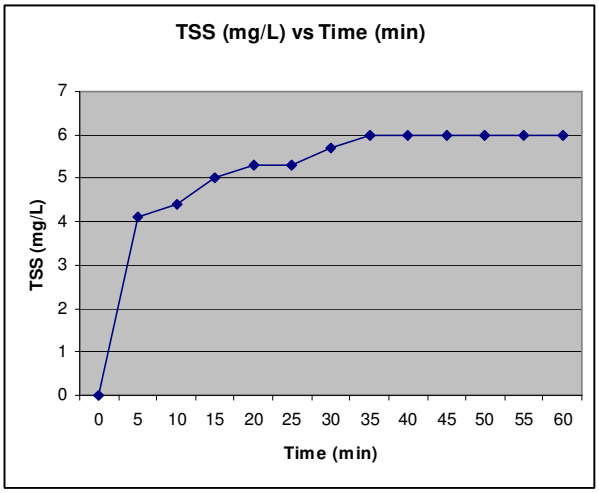

Fig. 4. Total Suspended Solid (TSS) versus time of experiment.

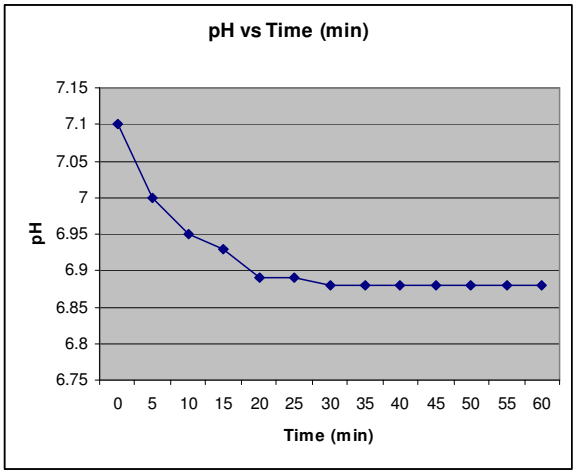

Fig.5. pH of polluted water versus time

III CONCLUSION

From the experiment it is proven that activity that produce smoke in the house such as cooking, smoking will add acidity and produce particles into the air. If repeatedly exposed to such condition, it will lead to other symptoms such as asthma, headaches and allergies.

Clean air is essential for optimal health and wellbeing. You might not be able to see them, but pollutants like dust, mould, smoke and other chemicals build up in the air in our homes, with harmful effects for our health. When we breathe them in, they exacerbate the symptoms of asthma and allergies and can make us feel generally run down.

The simple air filtrating system proved to have an impact in improving the quality of indoor air. It makes breathing easier and improves sleep and concentration levels. And for asthma and allergy sufferers it can greatly relieve the symptoms that make life unpleasant. Indoor air quality affects everyone's health - not just those of us with health conditions.

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