Fabrication of Simple Indoor Air Haze Purifier using Domestic Discarded Substances and Its Haze Removal Performance

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Abstract. Based on the concept of circular economy, discarded plastic bottles stuffed with discarded cotton, clothing and sofa cushion were used as pre-filter to remove big particles (dust and coal dust) in air and 4 L tap water in discarded plastic bottle was worked as an absorbing medium to dissolve the water soluble ions in air (SO\textsubscript{4}\textsuperscript{2-}, NO\textsubscript{3}-, NH\textsubscript{4}+, Cl\textsuperscript{-} and Ca\textsuperscript{2+}). Moreover, the internet control design was used in this homemade indoor air haze purifier to achieve the performance of remote control and intelligent management. The experimental results showed that this indoor air haze purifier can effectively reduce the level of indoor air haze and the air quality after 20 minutes treatment is higher than that of two commercial well-known air haze purifier.

Keywords: Recycling; Air purifier; PM2.5/PM10 Detection; Arduino mega2560.

1. Introduction
In China, air pollution is an increasingly serious problem with the rapid development of industrialization and urbanization [1]. In November 2013, the average haze days up to 4.7 days [2], many large-scale hazes appeared in the east-central China. Such long-term haze weather has caused much attention around the world. As indicated by Beijing Municipal Environmental Protection Bureau, the average concentration of PM2.5 was 89.5 mg/m\textsuperscript{3} in 2013; clear day was only accounted for 48% while the heavy pollution day accounted for 16%. Moreover, haze weather also caused the decreasing of inbound tourists [3]. Harmful particles, such as nitrogen oxides, sulfate and nitrate (less than PM2.5) would get into the lower respiratory tract during the respiration process, which can't discharge through the cough and may increase the risk of the asthma, allergy, and pneumonia and lung cancer. Therefore, the air pollution has serious consequences for the people's health, especially for the elderly, children and pregnant women [4, 5]. The survey results revealed that every additional 10μg/m\textsuperscript{3} of PM2.5 in the atmosphere increases the cardiovascular and hypertension patients by 6%-7% and 5%, respectively. Meanwhile, more than 65% of allergic asthma disease was related to dust in air. Except the outside haze, indoor haze also has adverse effects on human health. However, high price, low intelligence degree and high replacement frequency of filter are major disadvantages for the current air purifier. So, it is essential to prepare indoor air haze purifier with low cost, high purification efficiency, high intelligence degree.
According to the national standard (GB/T18801-2015), except energy efficiency, noise and accumulative purification rate, the key parameter for indoor air haze purifier is clean air delivery rate (CADR), which depended on filtering technique and material [6]. Various technologies, including low temperature asymmetric plasma, adsorption, negative ion and negative ion oxygen, were used to fabricate different indoor air haze purifiers. The popular commercial air haze purifiers are SHARP, PHILIPS, Matsushita, YADU, millet, Samsung, Blueair, 3M, Haier, Daikin, Honeywell, Midea, lake, TCL, ambitious, ADA house, GREE, MORAL, HUNTER, Aike, Dai Johnson, Whirlpool, Fujitsu, Airpal, ADA, Senmi, Cado and so on. These purifiers use the advanced technology with high purification efficiency while the production cost is pretty high. For example, the price of indoor air haze purifier ranges from 699 ¥ (domestic Xiaomi) to 4929 ¥ (SIEGENIA (Germany)). In addition, photo-catalysis, activated carbon and synthetic fiber were worked as main filtration medium, which needs extra processing and the regular replacement of filter will bring additional cost [6]. At the same time, the requirement of internet control for indoor haze removal was also increased with the improvement of people's living standards. In summary, air haze purifier with a high efficiency and intelligent has broad prospects.

The aim of the present paper is to fabricate a simple indoor air haze purifier using domestic discarded substances (plastic bottles, clothing, sofa cushion and cotton) as pre-filer to remove big particles and dissolve water soluble ions in air by using tap water. Moreover, the internet control design also applied in this homemade air haze purifier.

2. The System Design

2.1. Pre-filter System

The purpose of pre-filter is to remove the large particles in air by using domestic discarded substances (plastic bottles, clothing, sofa cushion and cotton) as pre-filer and reduce the pressure of the absorption system.

Table 1. List of pre-filter system items

| NO | Part name                        | Specification       | Quantity | Source/Manufacturer         |
|----|---------------------------------|---------------------|----------|----------------------------|
| 1  | Discarded plastic bottle        | 4.5 litre 500ml     | 1        | household garbage          |
| 2  | Kunlun mountain mineral water bottle | 45W D60mm         | 1        | Guangdong hailey group co. LTD |
| 3  | Electromagnetic air compressor  | plastic tube 3m    | 1        | household garbage          |
| 4  | Filter element 1: discarded clothing | D60mm             | 1        | household garbage          |
| 5  | Filter element 2: discarded sofa cushion | D60mm         | 1        | household garbage          |
| 6  | Filter element 3: discarded cotton | D60mm             | 1        | household garbage          |

3. Absorption System

The function of absorption system is to dissolve water soluble ions in air (SO$_2^+$, NO$_3^-$, NH$_4^+$, Cl$^-$ and Ca$^{2+}$) by using tap water as absorbing medium in discarded plastic bottle (4.5 liters).

3.1. Man-machine Interactive System and System Integration

The indoor air haze purifier is connected to the control system of the main control board with the Arduino Mega2560. The sensor parts of the control system can collect the data and then send it to the main control board. The main control panel can analyze the data, control the flow rate and switch of the pump through its feedback parts, and the data is displayed on the external LCD screen. Meanwhile,
system can send real-time data to external acceptor and computer to achieve the purpose of human-computer interaction.

**Table 2.** List of interactive system items

| No | Name                                           | Specification            | Quantity | Manufacturer |
|----|------------------------------------------------|--------------------------|----------|--------------|
| 1  | Arduino Mega2560 control panel                | 100 × mm 53 mm           | 1        | DFRO BOT     |
| 2  | PM2.5 laser dust sensor SEN0233               | 46mm×35 mm×20mm          | 1        | DFRO BOT     |
| 3  | I2C LCD1602 liquid crystal module             | 82 mm×35 mm×18mm         | 1        | DFRO BOT     |
| 4  | Solar panel power supply module               | 135 mm×110mm             | 1        | DFRO BOT     |
| 5  | Arduino Mega sensor expansion V2.4            |                          | 1        | DFRO BOT     |

**Figure 1.** Hardware design structure and physical object of control and monitoring system (1) and homemade indoor air haze purifier (2)

3.2. Efficiency of Indoor Air Haze Purifier

The removal efficiency of indoor air haze purifier can be calculated by eq. (1):

\[
R\% = \frac{y_1 - y_2}{y_1} \times 100\%
\]  

where \(y_1\) is haze concentration in the original air, \(\mu g/(m^3)\) and \(y_2\) is haze concentration after treatment, \(\mu g/(m^3)\).

4. Results and Discussion

The haze removal efficiency of this homemade air haze purifier was investigated. The filtration medium in pre-filter was respectively discarded cloth, sofa cushion and cotton and absorption medium in absorption system was tap water. The efficiency of indoor air haze purifier was calculated by eq. (1) and the corresponding results were shown in Figure 2. For comparison purposes, two commercial air purifiers also used to investigate their air haze removal ability. The experimental duration for all experiments was 20 minutes.
Figure 2. Experimental results of air haze removal rate (duration is 20 minutes).

It can be seen that the homemade air haze purifier can effectively remove indoor air haze. The removal efficiencies for PM2.5/PM10 after 20 minutes treatment were 63.10%/63.54% (empty discarded plastic bottles), 65.06%/64.72% (bottle stuffed with discarded cloth), 66.38%/66.82% (bottle stuffed with discarded sofa cushion) and 66.37%/66.07% (bottle stuffed with discarded cotton). Moreover, this purifier also possessed higher removal performance over two commercial air haze purifiers (41.88%/43.69%) and (47.04%/48.94%).
Table 3. Haze Removal Results (%) for one pass through indoor air haze purifier and two commercial air purifiers (%).

| Filter media                      | Data 1          | Data 2          | Average, %    |
|-----------------------------------|-----------------|-----------------|---------------|
| Discarded Empty bottle            | PM2.5 66.67%    | PM10 67.50%     | 63.10%        |
|                                   | PM2.5 65.92%    | PM10 65.06%     | 63.54%        |
| Discarded cloth in bottle         | PM2.5 75.95%    | PM10 75.58%     | 66.38%        |
|                                   | PM2.5 75.52%    | PM10 75.06%     | 66.82%        |
| Discarded sofa cushion in bottle   | PM2.5 69.12%    | PM10 69.74%     | 66.38%        |
|                                   | PM2.5 63.64%    | PM10 63.54%     | 66.82%        |
| Discarded cotton in bottle        | PM2.5 72.73%    | PM10 71.42%     | 66.38%        |
| Commercial #1 (Germany)           | PM2.5 37.08%    | PM10 37.37%     | 43.69%        |
| Commercial #2 (American)          | PM2.5 53.33%    | PM10 54.55%     | 48.94%        |

5. Summary
(1) Based on the concept of circular economy, an air haze homemade purifier was fabricated using discarded plastic bottles stuffed with discarded materials (cotton, clothing and sofa cushion) as pre-filter to remove big particles (dust) in air and 4 L tap water in discarded plastic bottles as an absorbing medium to dissolve the water soluble ions in air (SO$_4^{2-}$, NO$_3^-$, NH$_4^+$, Cl$^-$ and Ca$^{2+}$).

(2) The haze removal efficiencies of this homemade purifier for PM2.5/PM10 after 20 minutes were 63.10%/63.54% (empty discarded plastic bottles), 65.06%/64.72% (bottle stuffed with discarded cloth), 66.38%/66.82% (bottle stuffed with discarded sofa cushion) and 66.37%/66.07% (bottle stuffed with discarded cotton). This device can effectively reduce the degree of indoor air haze and its performance was better than that of commercial well-known air haze purifier #1(Germany) (41.88%/43.69%) and #2(American) (47.04%/48.94%).

(3) The internet networking integration solution was applied to design and control the device.

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7. Acknowledgement

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