VOL. 9, NO. 9, SEPTEMBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

# A STUDY ON THE DEVELOPMENT OF A DEODORIZATION UNIT FOR THE TOILET BIDET

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## ABSTRACT

Odorous toilet emissions are not convenient in modern, air-tight buildings. Thus, various deodorization methods are used but they do not provide a fundamental solution to the problem. In this paper, a novel deodorization method for bidet-attached toilets is proposed to enhance the deodorization performance of toilets. For this, experiments were conducted to evaluate the performance by attaching various fans and filters as well as passages to the bidet.

**Keywords:** toilet, bidet, deodorization, ventilation.

## INTRODUCTION

Today, increases in the quality of life have led to the widespread distribution of flush toilets, which have seen continuing advancement after the development of the siphon type toilet and siphon jet type toilets in the U.S. in 1882. Flush toilets are hygienic because a specific amount of water is collected in the trapway, preventing the inflow of stench from the sewer pipe and septic tank. Thus, the flush toilet has deeply rooted itself in the modern living space.

Dols *et al*. [1] and Chung and Wang [2] have reported that indoor air quality has a significant effect on the physical health of people. Sandberg and Blomqvist [3] and ASHRAE [4] found that the degree of air pollution indoors was on average higher than outside air. However, an effective ventilation system can improve the indoor air quality.

When using a toilet, ventilation of the bathroom air is necessary to create a pleasant environment as toilet use can create foul odors. While bathroom ventilation is a critical factor in environment improvement, expulsion of odors is not convenient in modern, air-tight buildings. As a result, a number of studies are being conducted on deodorization and sterilization within the bathroom. Tung *et al*. [6, 7] experimentally implemented a ceiling ventilation system in a mock-up bathroom. Fuh and Huang [8] calculated bathroom deodorization efficiency through numerical analysis. Seo *at al*. [9] proposed a suction system to the toilet in order to remove the odor and germs inside the toilet.

Toilet bidets are also used to create a more pleasant bathroom environment. Bidets are washing equipment used after using the bathroom where water is utilized to provide a local, partial shower effect through washing and drying. Bidets are hygienic and their use can help in the treatment of hemorrhoids, inflammation of the bladder, and vaginitis. Bidets can be attached without replacing the toilet, so the number of households using bidets is gradually on the rise. Therefore, direct deodorization and sterilization of the toilet through application of deodorization functionality to the bidet, which can be conveniently attached, can greatly contribute to the improvement of the bathroom environment.

Therefore, in this study, an HEPA filter (high efficiency particulate air filter) which can effectively remove foul odor from the air, was used in order to effectively enhance the bathroom environment. Also, two types of odor suction system where the odor can easily pass through the HEPA filter was attached to bidet toilets to verify the flow rate for the minimum deodorization performance.

## EXPERIMENTAL METHOD

In this study, two types of filters were considered, and fans appropriate for the filters were selected. Figure-1 shows the experimental equipment used to measure the pressure drop of the filter in relation to the flow rate. A model wind tunnel was manufactured and the pressure difference was measured after attaching a fan in the middle of the wind tunnel, and then mounting a filter to the front of the fan. Also, the duct outlet area was divided into 36 small areas of 1cm2 in order to measure the flow rate. Figure-1(a) shows the wind tunnel for the HEPA-A filter pressure drop test and Figure-1(b) shows the wind tunnel for the HEPA-B filter.

Next, two types of passages were fabricated based on the fan and filter types, as shown in Figure-2. Figure-2(a) shows the passage where the HEPA-A filter and suction fan can be attached. Here, the filter is inserted in the middle of the passage and the suction fan is attached at the passage end. Additionally, static pressure holes were made at the passage inlet, before and after the filter, and in front of the fan, in order to measure the pressure loss. Figure-2(b) shows the passage where the HEPA-B filter and blower can be attached. The blower is attached in the middle of the passage and the filter is attached at the passage end. Likewise, static pressure holes were made at the passage inlet, before and after the fan, and in front of the filter in order to measure the pressure loss.

To investigate the deodorization performance of the manufactured deodorization model, flow visualization experiment equipment were prepared as shown in Figure-3. After installing the deodorization system on the bidet, smoke was produced on the bottom of the toilet interior and the flow of the smoke was observed. Here, the bowl was partially blocked with an acrylic plate to investigate

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whether the smoke coming out of the opening was removed through the deodorization system. Also, in order to examine the deodorization performance according to the flow rate, experimentation was conducted by controlling the voltage of the suction fan in the range of 12V~18V while the blower was adjusted between the normal and power modes.

## RESULTS AND DISCUSSIONS

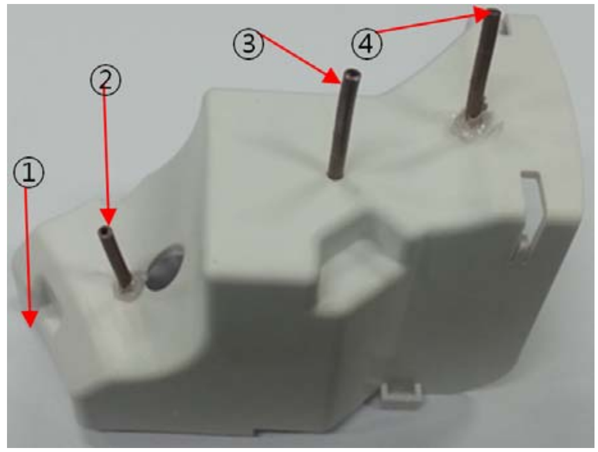
### Filter pressure drop measurement experiment

Pressure loss in the filter was measured in order to select the fan to use for the two HEPA filter types considered in this study. Figure-4 shows the pressure loss at the filter according to the flow rate. Both filter types showed an increase in the pressure loss proportional to the flow rate increase. Moreover, when the flow rate was 0.10 $m^3$/min, the pressure loss of the HEPA-A filter was found to be approximately 0.47 $mmH_2O$ and it was around 0.69 mmH2O for the HEPA-B filter. As such, the pressure loss of the HEPA-B filter was significantly greater than that of the HEPA-A filter. Additionally, for the flow rate of 0.20 $m^3$/min, the pressure losses were approximately 1.09 mmH2O and 1.62 $mmH_2O$ for the HEPA-A filter and HEPA-B filter, respectively. This result shows that the pressure loss increase rate of the HEPA-B filter in relation to the flow rate is substantially greater than that of the HEPA-A filter. Thus, the HEPA-B filter with a greater pressure loss requires a fan of larger capacity. In contrast, a fan of relatively smaller capacity can be used for the HEPA-A filter.

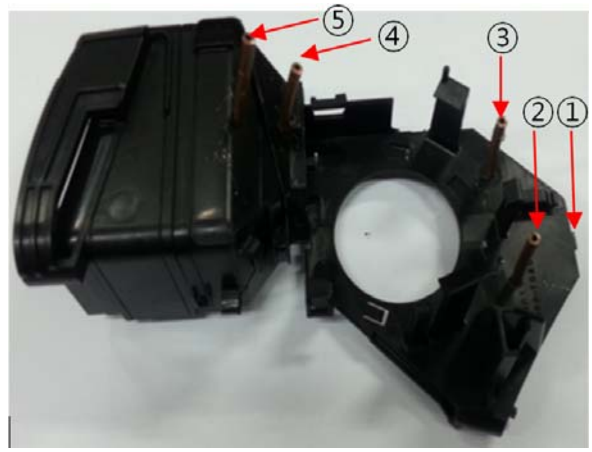
(a) HEPA-A filter

(b) HEPA-B filter

**Figure-1.** Wind tunnel for filter pressure drop measurement.



(a) Suction fan type passage.



(b) Blower type passage.

**Figure-2.** Blower type passage.

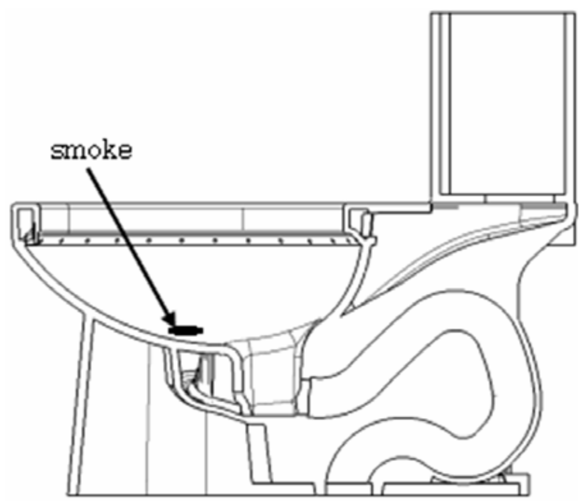



**Figure-3.** Deodorization performance experiment schematic.

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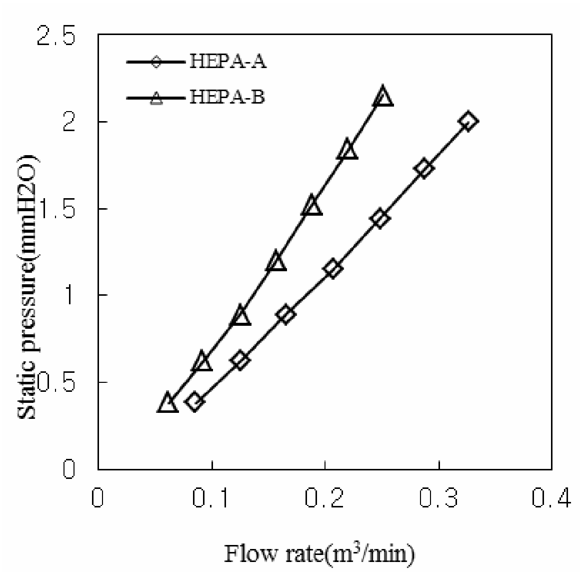


**Figure-4.** Pressure loss of the two filter types according to the flow rate.

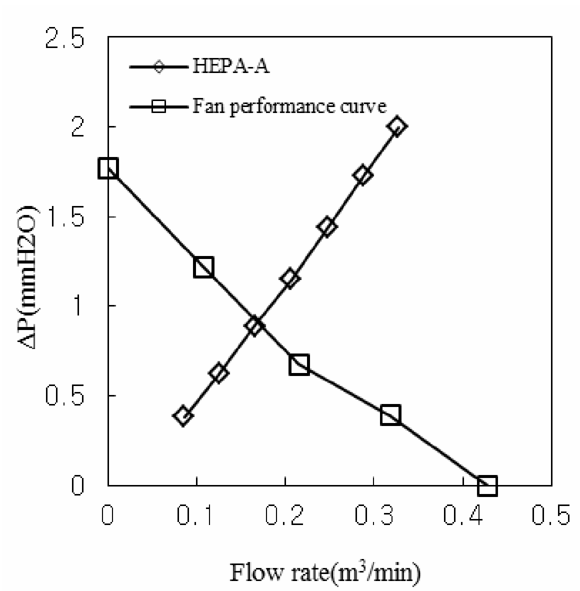


**Figure-5.** HEPA-A filter fan selection curve.

**Operation point for the fan and filter system**

The fan to be used in the deodorization system was selected considering the pressure loss of the filter. Figure-5 shows the fan performance and filter pressure drop curves when using the HEPA-A filter. In the case of the HEPA-A filter, a suction type fan was used, taking into consideration that the pressure loss is less than that of the HEPA-B filter. The pressure operating range of the fan is a maximum of 1.77mm$H_2O$ and the maximum flow rate is approximately 0.43 $m^3$/min. Here, the flow rate of the deodorization system is determined by the intersection point between the HEPA-A filter pressure loss curve and the fan performance curve. In the case of the selected suction fan, a flow rate of around 0.17 $m^3$/min is produced when using the HEPA-A filter.

For the HEPA-B filter, a blower was selected whose flow rate was greater than the suction fan since the pressure drag was greater than for the HEPA-A filter. The fan performance curve and filter pressure drag curve when using the HEPA-B filter are shown in Figure-6.

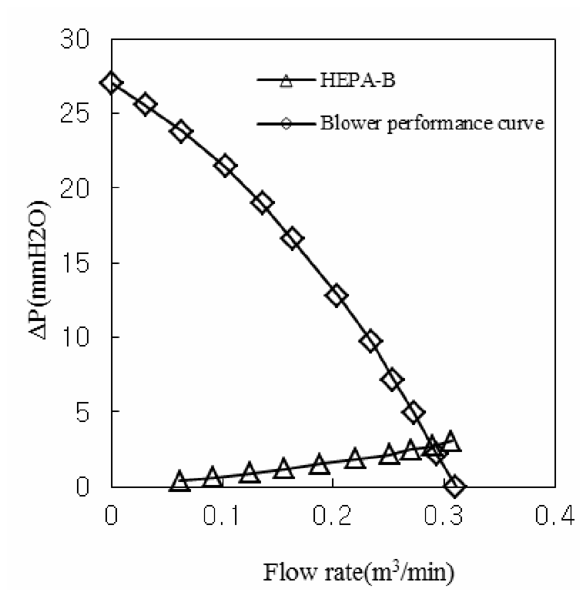


**Figure-6.** HEPA-B filter fan selection curve.

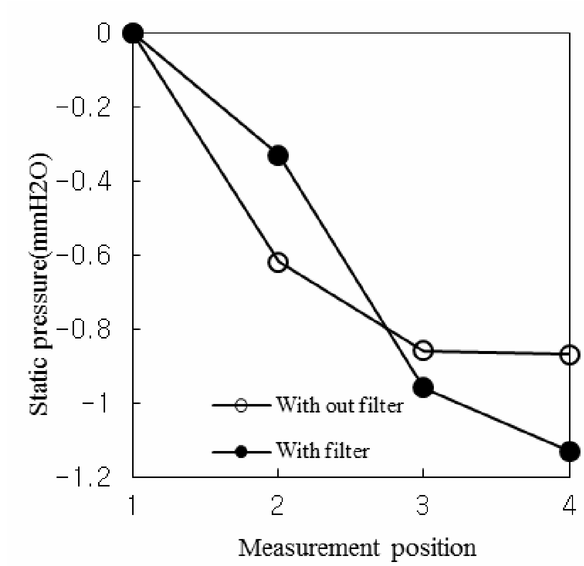


**Figure-7.** Pressure variation of the suction fan type passage according to the measurement position.

The selected blower has a maximum operating pressure of approximately 27.04 mm$H_2O$ and a maximum flow rate of around 0.31 $m^3$/min. When the HEPA-B filter was used, the maximum flow rate was approximately 0.29 $m^3$/min when using the blower in normal mode.

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**Passage pressure drop experiment**

Two passages were fabricated as shown in Figure-2, and the filter and fan were selected in order to create a sanitary ware deodorization system. Figure-7 shows the pressure loss based on whether or not a filter is used in the passage where a suction fan is attached. As can be observed in Figure-2, measurement point 1 is the passage entrance and the pressure here is atmospheric pressure. When there is no filter, the pressure drop between section 1 and section 2 or the passage entrance is most severe, and this is thought to be due to the narrow passage resulting from the bidet installation space. When no filter is attached, the total pressure loss at the passage is

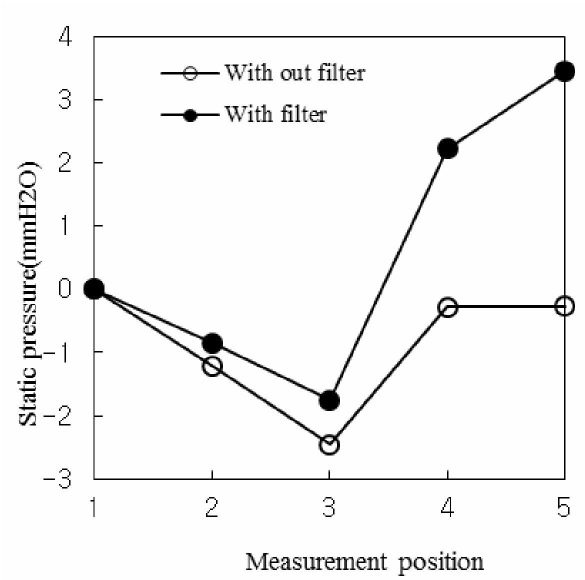
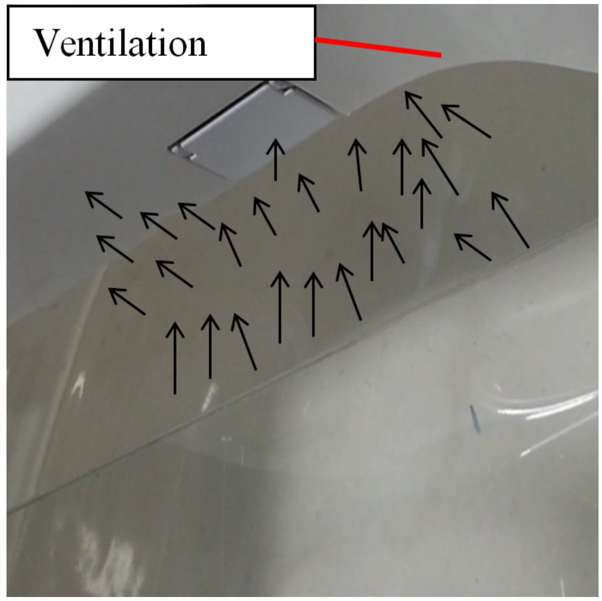


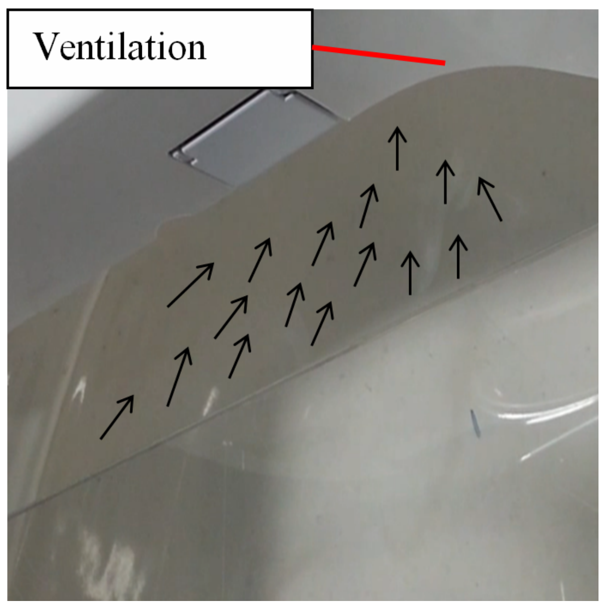

**Figure-8.** Pressure variation of the blower type passage according to the measurement position.

0.87 $mmH_2O$, while it is approximately 1.13$mmH_2O$ when a filter is attached. Therefore, the additional pressure loss from attaching a filter is approximately 0.26$mmH_2O$. From the fan performance curve, it can be observed that a flow rate of approximately 0.11$m^3$/min is produced for the passage with a filter and suction fan attached.

Figure-8 shows the pressure loss according to whether there is a filter at the passage where a blower is attached. For the case of no filter attached, the pressure decreases linearly up until measurement point 3 and increases again after passing the blower. When a filter is attached, the pressure decrease is relatively less until measurement point 3 due to the flow rate decrease. In addition, the pressure drop up to the filter front after passing the blower increases to approximately 5.80 $mmH_2O$, which occurs because of the filter causing stagnation of the flow and consequently a pressure increase.




(a) 12V deodorization performance experiment.




(b) 18V deodorization performance experiment.

**Figure-9.** Suction fan type passage deodorization performance.

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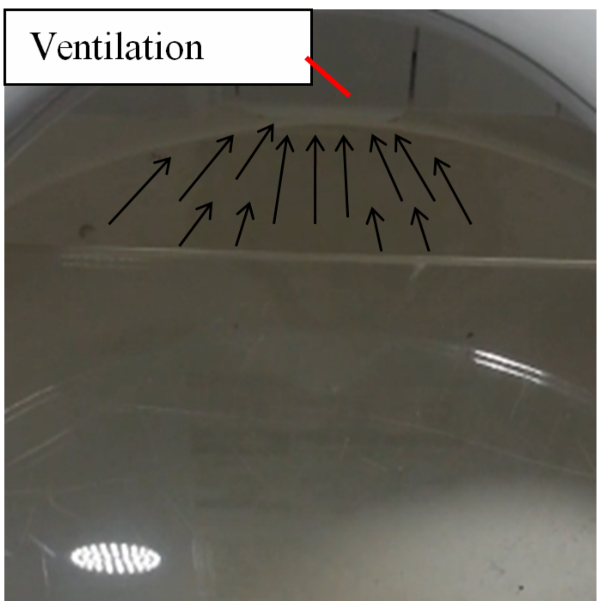
(a) Deodorization performance experiment with normal mode.




(b) Deodorization performance experiment with power mode.

**Figure-10.** Deodorization performance for the passage with the blower.

**Deodorization flow visualization**

Flow visualization experimentation was conducted to investigate the actual deodorization performance of a passage with two types of fan attached. Figure-9 shows the experimental result when using a suction type passage. The arrows in the Figure are the velocity vectors of the smoke. The smoke of the sanitary ware bowl interior was observed to leak out from the open gap rather than being completely discharged through the deodorization equipment of the bidet. This result reveals that the flow rate of approximately 0.11 $m^3$/min, produced when 12V was applied to the fan, cannot be expected to provide sufficient deodorization performance. However, after increasing the applied voltage of the fan to 18V leading to a flow rate of around 0.17$m^3$/min, the smoke within the bowl was observed to be discharged through the deodorization equipment rather than leaking through the gap. Accordingly, in order to obtain the minimum deodorization performance, a flow rate of at least 0.17$m^3$/min is necessary.

Figure-10 shows the experimental results for the blow type passage case. Observations of the experiment using the blower in normal mode revealed that the smoke did not leak out. The flow rate here was 0.22 $m^3$/min, showing that the deodorization performance was good. Moreover, the experiments using power mode showed that the smoke inside the bowl also did not leak out, but rather was discharged through the deodorization equipment at a high flow rate. Here, the flow rate was approximately 0.34 $m^3$/min, suggesting excellent deodorization performance. Therefore, it was found that rapid deodorization is also possible when using a blower.

**CONCLUSIONS**

In this study, in order to create a more pleasant bathroom environment, two types of fans, filters and passages were used to conduct deodorization performance experiments of sanitary ware bidet. The following conclusions were obtained.

a) Pressure drop experiments of the HEPA-A and HEPA-B filters showed that the HEPA-B filter case had a significant pressure drop of approximately 50%. This implies that using HEPA-B with superior deodorization performance requires a fan of greater capacity.
b) Results of wind tunnel experiments showed that the maximum flow rate using a suction fan with HEPA-A was approximately 0.17$m^3$/min while the maximum flow rate using a blower with HEPA-B was around 0.29$m^3$/min.
c) The usage of passage-A, HEPA-A, and suction fan produced a flow rate of approximately 0.11$m^3$/min, and the flow visualization experiment revealed that this flow rate did not result in sufficient deodorization. However, it was found that deodorization was possible when the flow rate was increased to 0.17$m^3$/min by increasing the suction fan rpm.
d) The usage of passage-B, HEPA-B, and blower produced a flow rate of approximately 0.22$m^3$/min, and the flow visualization experiment revealed that this flow rate resulted in sufficient deodorization. Also, operating the blower in power mode made rapid deodorization possible.

Further studies will be conducted for the reduction of actual odor concentration.

**ACKNOWLEDGEMENTS**

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0024805). In addition, this work was supported by the Human Resources Development program (No. 20134030200230) of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea Government Ministry of Trade, Industry and Energy.

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