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PERFORMANCE INVESTIGATION ON DEODORIZATION MATERIALS

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Abstract: The paper aims to create a design logical on gas removal material application for deodorization functions. Since the gas removal material varies by different type and different mechanism. Such as active carbon, silicon ball, photocatalyst and so on. Then we designed the performance test according to existing JEM standard, which is to evaluate air purifier performance on odor removal. Through the prototype design to add different purification materials one by one and test its performance to get the conclusion. Which is the active carbon materials have better removal efficiency of polar substance pollutants (formaldehyde and acetic acid), but the capability for non-polar VOCs removal (Ammonia) is weak. So compound active carbon materials maybe is a better choice for IAQ purification research to purify kinds of gas pollutant molecules.
Keywords: Deodorization; Active carbon; Photocatalyst; Air purifier

1 INTRODUCTION

Indoor air quality(IAQ) always being a hot topic that people focused on. For particle matter, such as PM1.0, PM2.5 and PM 10, we already have mature solution both on industry and domestic home appliances. We had PP, PET and PTFE materials to capture the particle matter due to mechanical and electrical effect[1]. But when referred to gas especially on odor, the mechanical will be much more complicated. Adsorb by active carbon is a direct and rapid way to removal the gas in the air. Adsorption has been classified as two types, which is physical adsorption[2] and chemical adsorption[3]. Physical adsorption is reversible and rapid, so it is easily to generate secondly pollutant due to the desorption[4]. Chemical adsorption is irreversible. Even it still has the situation on desorption[4], but the component desorbed is not the same as it is. Chemical adsorption is strong but not as fast as physical adsorption[3]. At the same time, the carbon filter itself has lifetime, not only with physical adsorption, but also with chemical adsorption.
Meanwhile, Titanium dioxide (TiO2) has attracted great attentions due to its low cost, minimal toxicity, advanced chemical stability, excellent performance and safety. It has been investigated to apply on purification area as photocatalyst Since Fujishima and Honda first used TiO2 for photolysis of water to produce hydrogen in 1972[5]. With the support of external light irradiance, electrons (e-) and holes (h+) generated, which migrate to the surface of TiO2. The electrons (e-) and holes (h+) can not only react with toxic and harmful organic substances, but also directly or indirectly convert the surrounding oxygen and water into ·OH with strong oxidation capacity by using its own oxidation reduction property, thus degrading toxic substances[6]. The whole reaction system is environmental friendly, but the reaction process is not fast and need to triggered by UV light.
This paper is to have a comparison test is to compare deodorization performance of different samples (Active Carbon, Silicon) with TiO2 in a DEMO, which is a prototype from Italy R&D. Get determination on the air purification prototype design on required carbon amount without or together with TiO2.

2 METHOD

2.1 Prototype Description

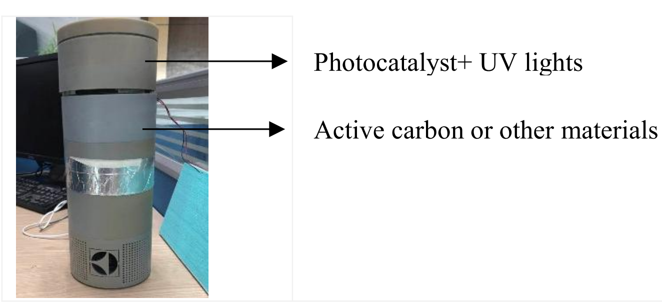

Figure 1 Prototype Display

2.1.1 Air purifier

Modified Air Purifier prototype which can use different materials as its filter which indicated in figure 1.

2.1.2 Filtration material

The filtration material we chosen for test is listed below and showed in figure 2.

1) VOC removal Active Carbon

Ingredient: Active carbon with formula additive which is special for VOC removal

2) Formaldehyde removal Active Carbon

Ingredient: Active carbon with formula additive which is special for formaldehyde removal

3) Common Active Carbon

Ingredient: Active carbon base without additive

4) Compound Active Carbon

Ingredient: Active carbon, attapulgite, diatom ooze, sepiolite. The last there kinds additive material are porous mineral material, which has large specific surface area, so they can absorb the gaseous pollutant and heavy metal in the gas. They have kinds of application in industrial purification, for example in edible oil purification, water purification etc.

Compound active carbon is the mixture of active carbon, attapulgite, diatom ooze, sepiolite. It is made of brightness ball, with diameter around 2mm.

5) Formaldehyde removal silicon ball

Ingredient: Silicon material is sphere ball base with vegetable source additive which can decompose organic pollutant.

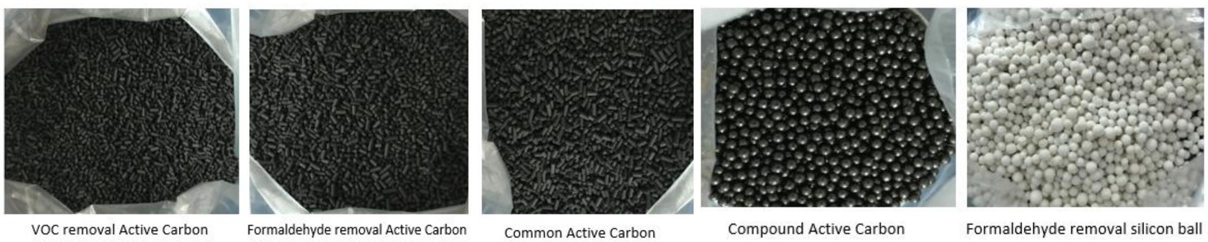

Figure 2 Overview of Filtration Materials

6) Phototype catalyst only, we called it PECO.

7) PECO +active carbon

2.1.3 Honeycomb filter base support on PECO module

Honeycomb filter base support is to install different filtration material for performance test showed in figure 3.

Filtration Area Size: 100mm*83mm*20mm.

Figure 3 Honeycomb Filter Base Support

2.2 Test Method

2.2.1 Test item

Formaldehyde removal rate, Acetic Acid removal rate and Ammonia removal rate.

2.2.2 Test equipment

1m3 test chamber with inject inlet and detect inlet showed in figure 4.

Figure 4 1m^3 Chamber Overview

Gastec Detector Tube Systems to detect the concentration of deleterious gas showed in figure 5.

Figure 5 Concentration Detection Tube

2.2.3 Deleterious gas preparation

Initial concentration should be in the scope of related test tube. Table 1 is the initial amount of pollutant added.

Table 1 Pollutant Drop Amount

VOC MATTER	Drop Amount	Initial Pollutant Amount / g
Formaldehyde	3	0.145
Acetic acid	3	0.057
Ammonia	14	0.740

2.2.4 Test time

0 ~ 60min.

Start counting when the concentration is in equilibrium level after injection.

2.2.5 Test standards

JEM1467-2015

3 RESULT

3.1 Determination of Filter Samples Amount

In the honeycomb filter on the air purify prototype, filter material can be filled with max.40g of active carbon particles, but the air flow drop will be larger. For same weight, different material has different thickness due to particle size and shape. The relation of weight and thickness for each sample are tested as Table 2.

Table 2 Filtration Material Description

No.	Filtration material	Test Sample Weight and Thickness		
		20g	30g	40g
1	VOC removal Active Carbon	10mm	15mm	20mm
2	Formaldehyde Removal Active Carbon	10mm	15mm	20mm
3	Common Active Carbon	10mm	15mm	20mm

4	Compound Active Carbon	8mm	12mm	15mm
5	VOC Removal Silicon Ball	8mm	12mm	15mm

Use No.1 VOC removal active carbon as benchmark to determine what weight can be used as benchmark weight for this comparison study at the first step. The data on figure 6 shows that the best amount of filter material is 30g, which has similar curve trend with PECO photocatalyst module. So 30g is determined as benchmark amount in the next study.

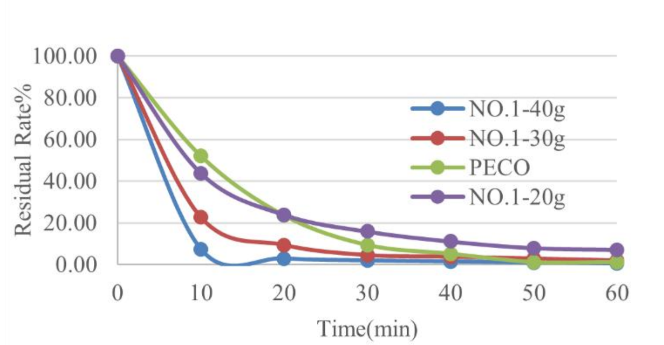

Figure 6 Acetate Removal Rate by No. Sample

3.2 Performance Test

3.2.1 Acetate removal efficiency

Table 3 Acetate Removal Test Result

Sampling Time	Removal Rate / %						
	NO.1	NO.2	NO.3	NO.4	No.5	PECO(TiO2)	PECO+NO.3
0min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10min	77.40	65.52	76.00	37.91	70.93	48.01	77.86
20min	90.72	86.21	84.80	65.13	90.22	76.52	92.08
30min	95.54	93.10	92.00	77.87	93.29	90.66	96.27
40min	96.29	94.48	94.80	82.98	95.43	94.87	97.20
50min	97.21	94.82	97.20	85.53	96.35	98.84	98.13
60min	98.14	95.85	97.60	88.94	97.57	98.84	98.60

Based on the table 3, we make the data curve to show the removal efficiency intuitively in figure 7.
Acetate Removal performance for 5 different materials Except for sample relatively equals to PECO filter. The performance of PECO+ active carbon didn't improve much compared to pure active carbon. The reason may be active carbon already excellent in formaldehyde and acetic acid removal. But maybe the combination of PECO will be good in extending lifetime of carbon[7].

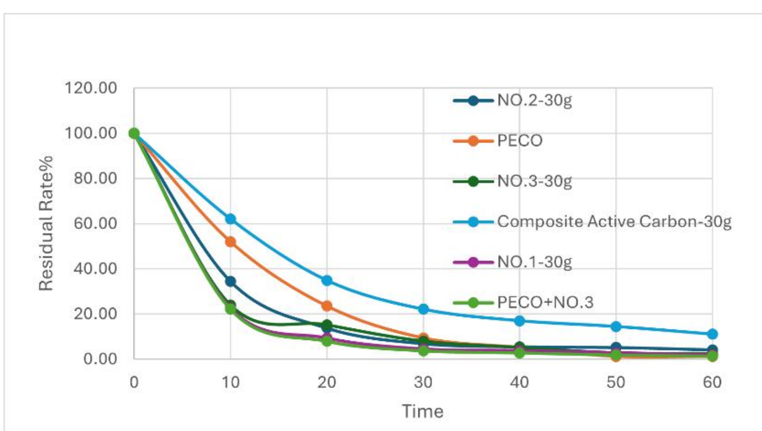

Figure 7 Actetate Removal Test Result

3.2.2 Ammonia removal efficiency

Performance for 5 different materials, all the samples that weigh 30g. The data shows in table 4, sample no.5 (silicon ball) has better than PECO photocatalyst, but the performance of other samples is far worse than PECO photocatalyst. So PECO and No.5 material is better than other solutions for Ammonia removal.

Table 4 Ammonia Removal Test Result

Sampling time	Removal Rate / %						
	NO.1	NO.2	NO.3	NO.4	No.5	PECO(TiO2)	PECO+NO.3
0min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10min	14.37	18.90	5.23	15.79	53.33	16.17	23.25
20min	15.71	20.96	9.07	19.30	66.67	25.41	29.49
30min	15.71	22.93	18.03	28.00	75.00	30.74	36.85
40min	17.14	22.93	19.31	29.76	81.65	32.07	42.92
50min	/	/	/	/	83.32	40.00	47.78
60min	/	/	/	/	83.32	46.18	51.42

Based on the table, we make the data curve to show the removal efficiency intuitively in figure 8.

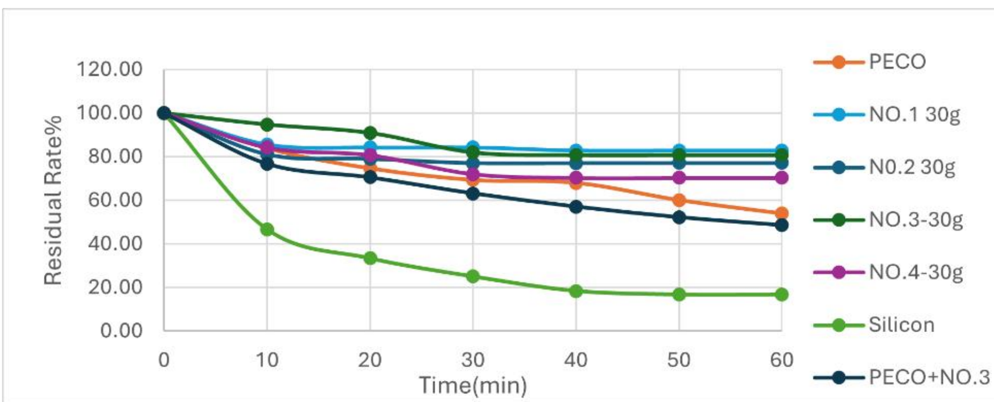

Figure 8 Ammonia Removal Test Result

In order to further understand the difference among PECO, carbon, PECO+carbon. We extended testing time from 60min to 180min.

Table 5 Ammonia Removal Test Result with Extend Testing Time

Sampling time	Removal Rate / %		
	PECO	Carbon	PECO+Carbon
0min	0.00	0.00	0.00
30min	39.21	5.43	31.47
60min	53.89	12.09	40.38
90min	63.71	17.19	51.71
120min	73.50	22.29	62.93
150min	78.43	22.29	70.35
180min	84.48	22.20	77.76

Based on the table 5, we make the data curve to show the removal efficiency intuitively in figure 9.

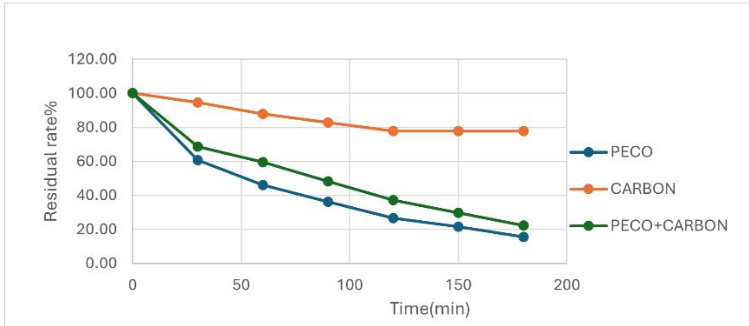

Figure 9 Long Term Ammonia Removal Test Result

The addition of PECO increased the Ammonia removal rate greatly. But due to the air resistance, the performance of PECO+carbon is lower than PECO itself.

Molecule polarity is one of molecule attribute based on molecule configuration and electric charge in chemical science field[8]. In this rule, molecules are classified as polar and non-polar. In the group of molecules of polar, they attract each other, and exclude non-polar molecules in the same time. For non-polar molecules group, they are same. In purification process, if both filter material and pollutant are in the same group, pollutant will be absorbed easily[8]. Ammonia is non-polar molecules, which means the filter material are non-molecule groups.

3.2.3 Formaldehyde removal efficiency

Based on the table 6, we make the data curve to show the removal efficiency intuitively in figure 10.

Table 6 Formaldehyde Removal Test Result

Sampling time	Removal rate / %						
	NO.1	NO.2	NO.3	NO.4	No.5	PECO(TiO2)	PECO+NO.3
0min	0.00	0.00	0.00	0.00	0.00	0.0	0.00
10min	50.09	73.88	71.43	22.35	71.43	16.7	70.53
20min	64.01	86.94	91.41	33.33	89.29	50.0	89.95
30min	72.32	95.10	94.62	37.62	94.64	66.7	96.06
40min	/	98.03	97.31	48.76	99.10	90.0	97.89
50min	77.86	99.67	99.10	55.44	99.64	93.8	98.80
60min	80.39	99.67	99.46	59.80	99.64	96.9	98.81

For 5 different material, with formaldehyde removal, sample no.2, 3, 5 have similar performance with PECO photocatalyst. Sample no.1 (VOC removal type) and No.4 (bare carbon material) have worse performance for formaldehyde. The performance of PECO+ active carbon didn't improve much compared to pure active carbon. The reason may be active carbon already excellent in formaldehyde and acetic acid removal. But maybe the combination of PECO will be good in extending lifetime of carbon[7].

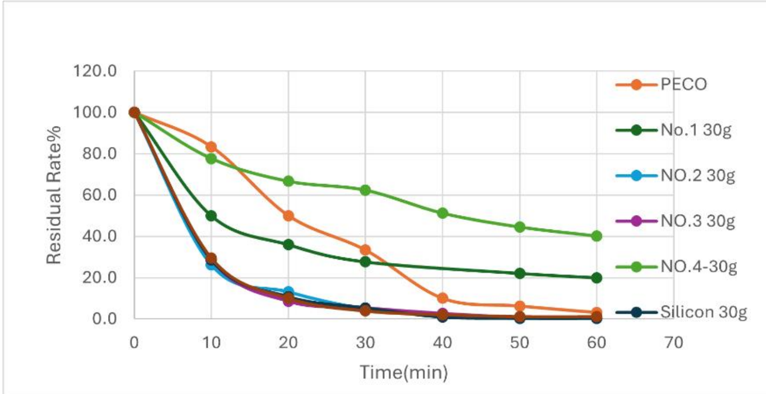

Figure 10 Formaldehyde Removal Test Result

4 CONCLUSION

All the samples have good removal efficiency as PECO photocatalyst, except sample no.4 (compound active carbon) is worse than PECO. Which means bare carbon material is not efficient stand alone

In all, the study shows that active carbon materials have better removal efficiency formaldehyde and acetic acid pollutants, but the capability for VOCs removal (such as Ammonia) is weak. So combination with carbon material together with PECO is good but requires optimization for amount of carbon usage or combined solution will extend the carbon filter lifetime.

Molecule polarity is one of molecule attribute based on molecule configuration and electric charge in chemical science field[8]. In this rule, molecules are classified as polar and non-polar. In the group of molecules of polar, they attract each other, and exclude non-polar molecules in the same time. For non-polar molecules group, they are same. In purification process, if both filter material and pollutant are in the same group, pollutant will be absorbed easily. Ammonia is non-polar molecules, formaldehyde and acetate are polar molecule. In the test, the data shows the regular of polarity.

The study shows that active carbon materials have better removal efficiency of polar substance pollutants (formaldehyde and acetic acid), but the capability for non-polar VOCs removal (Ammonia) is weak. So compound active carbon materials maybe is a better choice for IAQ purification research to purify kinds of gas pollutant molecules.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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