● Novel multi-odor gas adsorbent 「KESMON® NS-60」

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1. Introduction

In recent years, with rising awareness of comfort and hygiene in living spaces, products with deodorization processing have become widespread. Advances have been made in technology to add deodorization functions to fibers, resins, paper products, etc., and it is now widely used in housing interiors such as wallpaper and curtains, clothing, bedding, masks, nursing care products, automobile interiors, etc. These not only reduce household and body odors, but also contribute to ensuring a hygienic environment and psychological comfort. On the other hand, deodorization processed products vary in performance depending on the material and processing method, making it difficult for consumers to judge their effectiveness and safety. For this reason, certification mark systems by third-party organizations have been established in Japan, and the SEK Mark[1] established by the Japan Textile Evaluation Technology Council (SEK) for the textile industry is a representative example. The SEK Mark is given to textile products that have been tested for household odor components such as ammonia, acetic acid, and aldehydes, and have been shown to meet certain performance standards.

In recent years, demand for odor reduction of recycled resin has increased. Recycled resins are made from used plastic products or waste plastics that have been collected and reprocessed to make them reusable. However, one problem with recycled resins is that they generate odors derived from impurities during production and use. Since there is a wide variety of recycling sources, recycled resins generate a composite odor that is a mixture of various types of gases. Therefore, conventional adsorbents that are effective only for specific odor components may not exhibit sufficient performance. Furthermore, since partial use of recycled resins will be mandated for the production of new vehicles in the European automotive industry going forward[2], the introduction of recycled resins is also progressing in Japan. In addition, there is a growing trend in utilizing metals, glass, and rubber as recycled materials, all of which pose the challenge of generating composite odors derived from the materials. Due to these issues, the demand for multi-odor adsorbents that exhibit high adsorption performance against composite odors is expected to increase in the future.

2. Existing deodorants

Typical deodorants that have been put to practical use include activated carbon and zeolite. Activated carbon has been widely used as a general-purpose deodorant because of its large specific surface area and ability to adsorb a wide variety of odors. However, because it is a physical adsorption-type deodorant, it tends to re-release gas molecules that were once captured due to changes in environmental conditions, making it difficult to maintain sustained deodorization performance. Furthermore, because activated carbon is a black powder, it has the limitation of detracting from aesthetic appeal when applied to products where appearance is important. Zeolite is also porous and has a regular pore structure that exhibits excellent deodorization performance against polar gases. However, since zeolite is a strongly hydrophilic material, water molecules preferentially occupy the pores in high-humidity environments, which significantly reduces its deodorization effect.

On the other hand, there are chemical adsorption-type deodorants that show high deodorization effects by chemically reacting with certain odors such as basic gases, sulfuric gases, and acidic gases. Although chemical adsorption-type deodorants are extremely effective in deodorizing specific odor gases, it is difficult for a single deodorant to adsorb multiple types of gases, so multiple grades must be combined to handle composite odors consisting of a mixture of multiple different odors. To address these issues, we have developed KESMON NS-60, a new multi-odor gas adsorbent that compensates for the weaknesses of conventional materials and exhibits stable performance against a wider range of odor gas components. This article introduces the adsorbent.

3. New multi-odor gas adsorbent KESMON NS-60

KESMON NS-60 is a new multi-odor gas adsorbent consisting of Metal Organic Frameworks (MOFs). MOF is a porous material that has attracted much attention in recent years because of its ordered crystal structure composed of metal and organic ligands, as well as high specific surface area (**Fig. 1**)[3]. Since the pore size and surface properties can be controlled by changing the combination of metal species and organic ligands, it can be designed specifically for each application. This high degree of freedom is a major highlight. Currently, MOFs are being considered for application in a wide range of fields, including adsorption, separation, and catalytic reactions, and have shown great potential as functional materials.

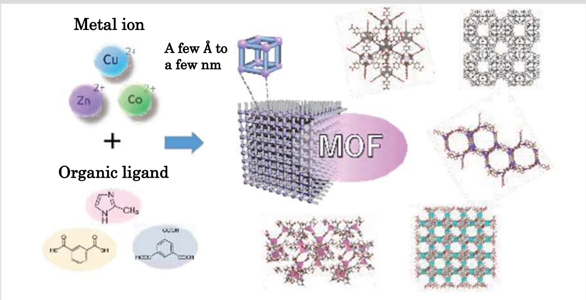

Figure 1: Conceptual diagram of MOF

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The deodorization mechanism of KESMON NS-60 is based primarily on two factors: physical adsorption and partial chemical adsorption. KESMON NS-60 takes various odor components into its pores by physical adsorption and exhibits high deodorization effects. Furthermore, for some odor components such as ammonia, acetic acid, and isovaleric acid, adsorption also occurs via chemical interaction, so that re-release is less likely to occur than with physical adsorption-type deodorants such as activated carbon. In addition, KESMON NS-60 has excellent water resistance and heat resistance, and demonstrates stable deodorization performance even in environments with significant changes in humidity and temperature.

3.1 Characteristics of KESMON NS-60

Because KESMON NS-60 is a white powder, it can be post-processed into fibers, etc. or molded into resins without compromising the color or appearance of the host material (**Fig. 2**). **Table 1** shows the physical properties of KESMON NS-60. Its stable crystalline structure makes it heat-resistant up to 350°C, and it can be kneaded into general-purpose resins such as polypropylene and polyester.

Figure 2: KESMON NS-60

Table 1: Typical properties of KESMON NS-60

Appearance	White powder
Average particle diameter D50	Approx. 20 µm
Heat-resistant temperature	350°C
Aerated bulk density	0.14
Specific surface area	800 to 1100 m^2/g

3.2 Deodorization performance of KESMON NS-60

KESMON NS-60 exhibits deodorization performance against various types of odor components. First, we evaluated the deodorization performance of KESMON NS-60 powder against eight gases with high deodorization needs, including ammonia, acetic acid, and acetaldehyde. We carried out the test by sealing the powder in a test bag, injecting gas adjusted to a predetermined concentration, sealing the bag, leaving it at room temperature, and measuring the residual gas concentration in the bag with a gas detector tube at regular intervals to evaluate changes over time. **Fig. 3** shows the results. A lower residual gas concentration over a shorter time indicates a deodorant with faster deodorization speed and larger deodorization capacity. The results show that KESMON NS-60 exhibits deodorization performance superior to that of activated carbon for various gases.

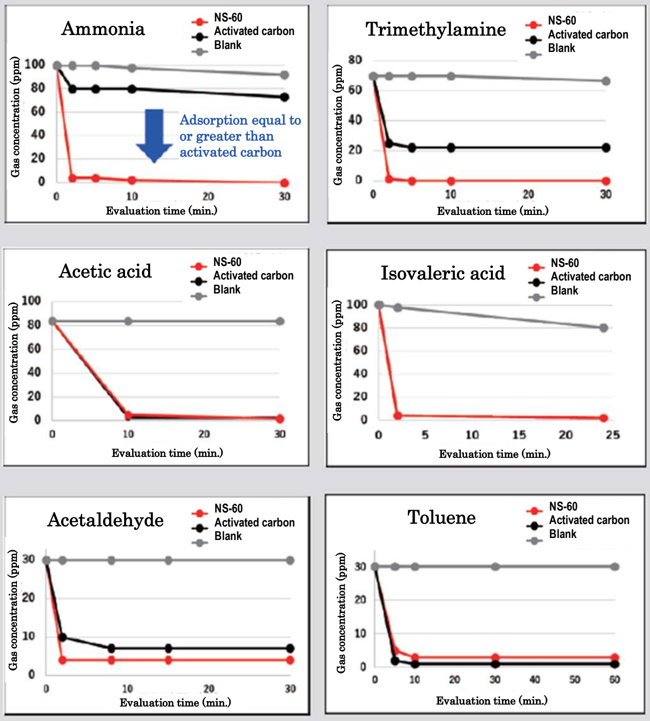

Figure 3: Deodorization performance of KESMON NS-60 against various gases

We also evaluated the deodorization performance using a sensory evaluation method, in which human evaluators smell and rate the odor. We conducted evaluations against tetradecane, one of the volatile organic compounds (VOCs)[4] and a causative substance of sick building syndrome, and 2-nonenal, a major component of age-related body odor. We carried out the test by injecting a solution of tetradecane or nonenal into an Erlenmeyer flask containing the powder and letting it stand sealed for 2 hours so that each compound would volatilize into gas inside the flask. After standing, six evaluators assessed the headspace inside the Erlenmeyer flask by smell and rated it according to the six-grade odor intensity scale (**Table 2**). **Fig. 4** shows the results. KESMON NS-60 reduced tetradecane with an odor intensity of 3 and nonenal with an odor intensity of 3.5 to below 1, demonstrating its high deodorization effect against VOCs and age-related body odor.

Table 2: Six-grade odor intensity scale

Odor intensity	Judgment
0	No odor
1	Barely perceptible odor
2	Weak odor
3	Easily perceptible odor
4	Strong odor
5	Intense odor

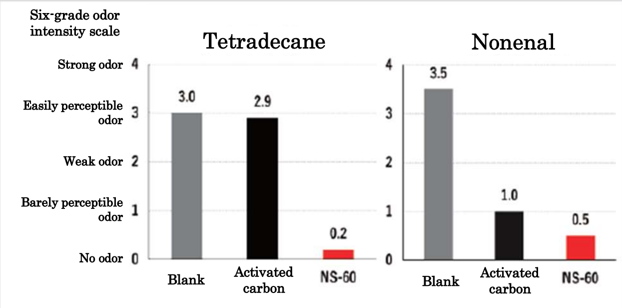

Fig. 4: Deodorization performance against nonenal and tetradecane

These results indicate that KESMON NS-60 has the characteristics of a multi-odor gas adsorbent and that it has potential for a wide range of applications in indoor spaces and household products.

3.3 Deodorization performance of processed products

3.3.1 Deodorization performance of nonwoven fabric post-processed with KESMON NS-60

To evaluate the deodorization performance of products coated with KESMON NS-60 powder using a binder., we prepared post-processed nonwoven fabrics and evaluated their deodorization performance. First, we dispersed KESMON NS-60 in water and added a binder to prepare a uniform coating solution. We applied the resulting coating solution uniformly to the PET nonwoven fabric serving as the substrate, and dried it sufficiently to prepare a coated nonwoven fabric on which KESMON NS-60 was deposited at 1 g/m^2 or 2 g/m^2. We evaluated the deodorization performance of the prepared nonwoven fabric in accordance with the certification standards for the SEK Deodorization Processing Mark[1)]. We cut the nonwoven fabric coated with KESMON NS-60 into 10 × 10 cm test specimens, placed each in a test bag, sealed it, and injected with 3 L of acetic acid gas or ammonia gas adjusted to a specified concentration. After leaving it standing for 2 hours at 25°C, we measured the residual gas concentration in the test bag with a detector tube. As a blank test, we also prepared a test bag without nonwoven fabric under similar conditions, and measured the residual gas concentration. Based on the concentration values obtained, we calculated the odor reduction rate (%) using **Equation 1**.

Odor reduction rate (%) = $(S_b - S_m)/S_b \times 100$ ... (**Equation 1**)

S_b: Residual gas concentration in blank test

S_m: Residual gas concentration in the test bag containing the test specimen

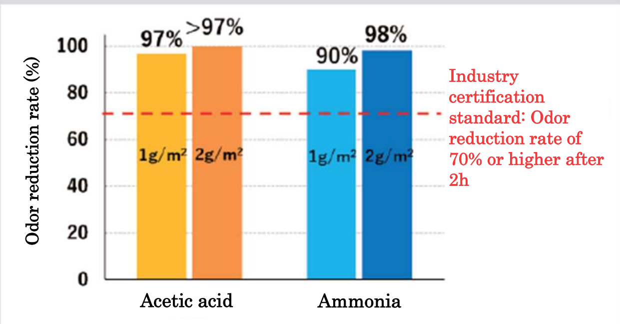

Figure 5: Deodorization performance of nonwoven fabric post-processed with KESMON NS-60

We found that KESMON NS-60 was highly effective in deodorizing acetic acid gas and ammonia gas even when coated into nonwoven fabrics (**Fig. 5**). The certification standards for obtaining SEK Deodorization Processing Mark[1)] require an odor reduction rate of 70% or higher. The odor reduction rate of the coated with KESMON NS-60 nonwoven fabric increased with the spreading amount, and both fabrics met the SEK Mark certification standards for both acetic acid gas and ammonia gas.

3.3.2 Deodorization performance of KESMON NS-60-kneaded resin

We evaluated the deodorization performance of KESMON NS-60-kneaded fiber as a resin compound. For the resin, we selected PET resin, which is widely used in deodorization-processed textile products. We ground KESMON NS-60 powder to an average particle size of approximately 4 µm so that it could be kneaded into fibers with a fiber diameter of 10–20 µm. First, we prepared the KESMON NS-60 master batch by mixing PET resin pellets and KESMON NS-60 powder, feeding the mixture into a twin-screw extruder, and melting and extrusion-molding the resin while kneading it with the screws. Then, using the resulting master batch, we manufactured KESMON NS-60-kneaded PET fibers (yarn and wadding) on a melt-spinning machine, with the KESMON NS-60 content set to 2 wt% (**Fig. 6**).

Figure 6: Yarn and wadding processed with KESMON NS-60

Fig. 7 shows the scanning electron microscope (SEM) images of the surface of the manufactured KESMON NS-60-kneaded fiber. The SEM image shows the presence of KESMON NS-60 on the PET fiber surface.

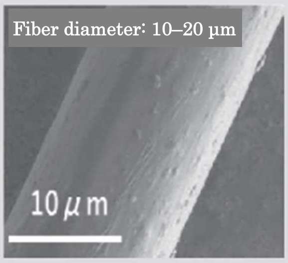

Figure 7: SEM image of KESMON NS-60-kneaded fiber

We evaluated the deodorization performance of KESMON NS-60-kneaded fiber in accordance with the certification standards of SEK Deodorization Processing Mark[1)]. We placed 2.4 g of the deodorizing fiber in a test bag, injected 3 L of acetic acid gas or ammonia gas adjusted to the specified concentration, and sealed the bag. We left it standing for 2 hours at 25°C, then measured the residual gas concentration in the test bag. As a blank test, we also prepared a test bag without KESMON NS-60-kneaded fiber under similar conditions, and measured the residual gas concentration. Based on the difference in concentration between the blank test and the test bag containing KESMON NS-60-kneaded fiber, we calculated the odor reduction rate (%) using **Equation** 1. **Fig.** 8 shows the test results. PET fiber kneaded with KESMON NS-60 exhibited an odor reduction rate of 70% or more for both acetic acid gas and ammonia gas, and satisfied the certification standards of SEK Deodorization Processing Mark. As shown above, KESMON NS-60 demonstrated high deodorization effect even after being kneaded into resin and processed.

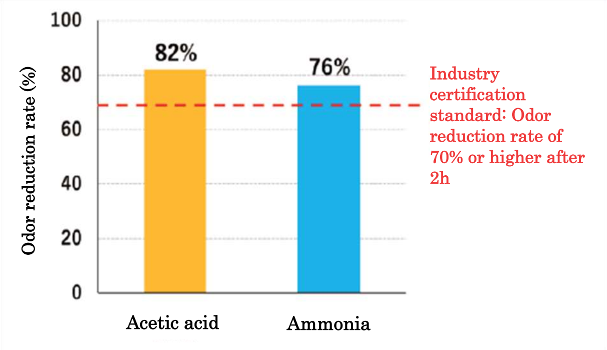

Figure 8: Deodorization performance of KESMON NS-60-kneaded fiber

3.4 Deodorization performance of KESMON NS-60 against composite odor

We evaluated the performance of KESMON NS-60 against composite odors generated from recycled PP resin. We measured recycled PP resin to a certain weight and placed it in a test bag for sensory evaluation. We also added KESMON NS-60 at 2 wt% of the resin weight, and allowed the odor components to evaporate inside the bag by heating at 80°C for 2 hours in a sealed state. After heating, we let the sample cool to room temperature and carried out sensory evaluation for odor generated in the bag. For comparison, we also prepared samples in the same manner using zeolite, a general-purpose deodorant, and carried out evaluation. We used the six-grade odor intensity measurement method in **Table** 2 to determine odor intensity, and had six human evaluators rate the odor. **Fig.** 9 shows the results of the test in which the deodorization effect was evaluated by comparing the results between bags with deodorant added and bags without deodorant (blank).

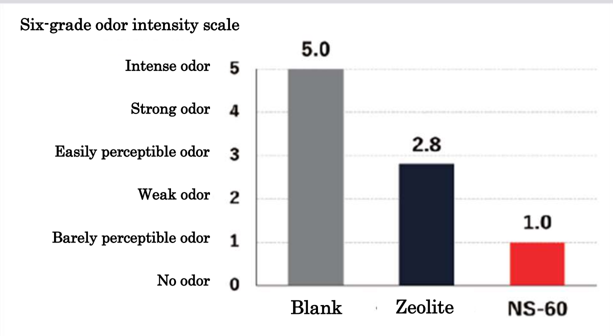

Figure 9: Deodorization effect of KESMON NS-60 on recycled resin odor

Without deodorant, the composite odor from the recycled resin had an odor intensity of 5. The zeolite-added sample reduced this to only about 3, whereas the sample with KESMON NS-60 reduced the composite odor from the recycled material to an intensity of 1. The results showed that KESMON NS-60 was effective in reducing the unique composite odor generated from actual recycled resin.

4. Conclusion

We developed KESMON NS-60, a new multi-odor gas adsorbent that exhibits higher deodorization effects against various odor components than conventional deodorants such as activated carbon and zeolite. This material can be post-processed into fibers or kneaded into various resins to impart a high deodorization effect. We hope that more end users will use KESMON NS-60 in the future so that comfortable living spaces are provided to as many people as possible. We also hope to contribute to the SDGs through the use of recycled materials.

Reference

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