

## Overview of Antibacterial Agents and Antibacterial Products

### Introduction

The term microorganisms refers to living organisms too small to see with the naked eye. Microorganisms come in various types. Common examples from daily life include bacteria linked to food poisoning and viruses. To prevent adverse effects from microorganism propagation, it is important to select and use antibacterial agents suited to the microorganism type and the usage environment.

ThreeBond has a lineup of numerous antibacterial agents intended to make automobile interiors more comfortable for people. Products for use in locations other than automobiles, such as on public transportation and in homes, have also been released in recent years.

In this article, the authors describe core approaches taken with antibacterial agents and two antibacterial products from ThreeBond: the car air conditioner refresher ThreeBond 6721P and the visible light responsive photocatalyst spray ThreeBond 6735.

Hereafter, ThreeBond in product names is abbreviated as TB.

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## 1. Types of Microorganisms

We are surrounded by a wide variety of microorganisms with different sizes and structures (Figure 1). To limit microorganism propagation, it is important to select an appropriate antibacterial agent based on the type of microorganisms and the usage conditions, including the temperature, humidity, sunlight exposure and the material to which the substance is applied.<sup>1)</sup>

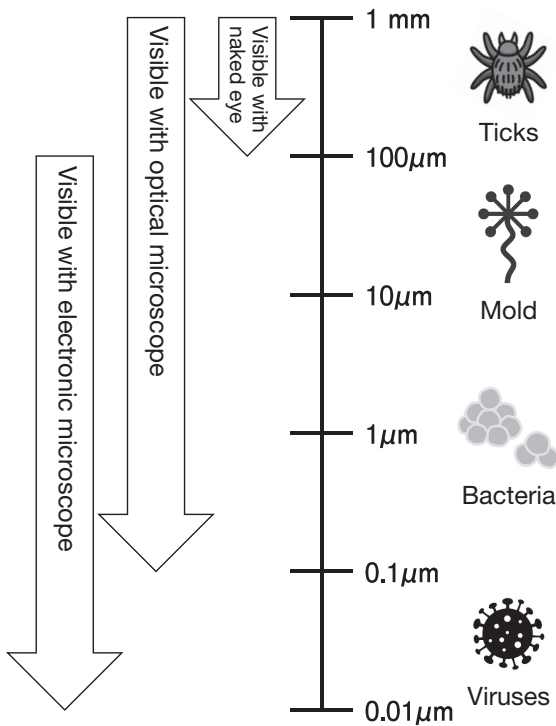


Fig. 1 Microorganism Sizes<sup>1)</sup>

\* Ticks are not microorganisms, but have been included for size comparison purposes.

Bacteria are prokaryotes measuring about 1 to 5  $\mu\text{m}$  and mainly propagate through division. They can be broadly divided into two categories based on differences in the outer cell membrane structure. Gram-negative bacteria are coated with liposaccharides (LPS), while gram-positive bacteria do not have LPSs.<sup>2)</sup> Depending on the species, bacteria come in various shapes and display various characteristics, including ball-shaped cocci bacteria, rod-shaped bacillus, autotrophic bacteria that use  $\text{CO}_2$  as nutrition for growth, heterotrophic bacteria that derive energy from organic compounds, photosynthetic bacteria capable of growing with energy from light and chemoautotrophic bacteria that can derive energy for growth from the oxidation of organic compounds.

Mold differs from bacteria because its nucleus is inside the cell wall. It is found in various forms and environments. If mold is unable to propagate due to changes in environmental conditions, such as temperature, humidity, nutrition or pH, it can create spores to preserve its genes,

then propagate when the environment improves. As a result, even if removal is performed to the point that mold is no longer visible, a small amount of remaining mold can be sufficient for propagation to occur once more.

Viruses are extremely small microorganisms measuring about 0.01 to 0.3  $\mu\text{m}$  and cannot be seen with standard optical microscopes. Unlike other microorganisms, they cannot propagate alone. Instead, they propagate using the synthesis functions of other living organisms, referred to as hosts. Viruses are therefore sometimes said to exist in a gray area between living organisms and non-living objects.<sup>3)</sup> Given the wide variety of structures, species and propagation methods described here, setting appropriate environmental conditions and selecting an appropriate antibacterial agent are important considerations in limiting bacteria propagation.

## 2. Bacteria Reduction Methods

Bacteria reduction methods can be divided into three main categories.

The first category is sterilization. Sterilization refers to the of killing of harmful microorganisms such as pathogenic bacteria. An everyday example is taking antibiotics through medicine and similar products. When all bacteria are killed, the result is described as sterile.

Bacteria elimination methods include high-pressure steam-based elimination using high-temperature, high-pressure steam in a device called an autoclave, and sterilization using toxic ethylene oxide gas. However, the need for special equipment makes these bacteria elimination methods difficult to implement in a normal environment.

The second category is disinfection. Disinfection refers to removing microorganisms from a particular environment or reducing their number in said environment. Disinfection also includes hand washing and gargling.

The third category is bacterial resistance. Bacterial resistance is a general term for sterilization, disinfection, bacteria elimination and propagation inhibition. Bacterial resistance includes products that can be applied in advance to prevent the occurrence or propagation of bacteria.

ThreeBond develops products specialized for bacterial resistance to maintain a hygienic environment inside automobiles for longer without using special equipment.

Bacterial resistance can be broadly divided into physical, chemical and biological methods. Physical methods include reducing bacteria numbers using heating and filtration. With chemical methods, bacteria are removed using drugs and disinfectants. Biological methods include reducing propagation through pH and water activity control.<sup>4)</sup>

### 3. Antibacterial Agents

Antibacterial agents can be separated into two broad categories: organic and inorganic.

Organic antibacterial agents can be further subdivided into natural products and synthetic products. Allyl isothiocyanate, which is contained in wasabi, and catechin, which is found in tea, are natural products known as highly safe antibacterial agents. Synthetic products include alcohol-based and surfactant-based products. Organic antibacterial agents are fast acting, but not long lasting, and are therefore used when immediate effects are desired.

Inorganic antibacterial agents, meanwhile, work based on the antibacterial effects of metal ions of materials such as copper, silver, and zinc. These antibacterial agents last longer and are more heat resistant than organic antibacterial agents, making them easier to add to processed products.<sup>5)</sup> Tungsten oxide and titanium oxide are examples of such inorganic antibacterial agents and exhibit antibacterial effects through photocatalytic reactions. Catalysts are substances that support the progression of reactions by lowering the activation energy required for substances to produce a chemical reaction. Among catalysts, photocatalysts use energy from light to create components that attack bacteria, reducing the occurrence and propagation of bacteria. Details of the mechanism are shown later in this article (Figure 2).

Photocatalysts enter an excited state through energy obtained from light. When a photocatalyst is in an excited state, it reacts with oxygen and water in the air, producing superoxides and hydroxyl radicals. These hydroxyl radicals and superoxides oxidize and break down the cell surfaces and outer membranes of organisms such

as bacteria and viruses. The photocatalyst then returns to its ground state. However, it enters an excited state again when exposed to light once more, contributing to the production of hydroxyl radicals and superoxides. In this way, the photocatalyst itself is not altered by the reaction, meaning it remains in place and provides semi-permanent effects.

### 4. ThreeBond Products

In this section, the authors describe two antibacterial products from ThreeBond that can be used in automobile interiors. The antibacterial agents listed are not a comprehensive list. Contact a ThreeBond sales representative for further information.

#### 4-1 TB6721P

The car air conditioner refresher TB6721P is an antibacterial agent in aerosol form for use on automobile air conditioning ducts and evaporators. Evaporators are heat exchangers that cool air. This makes them susceptible to condensation, providing a favorable environment for bacteria and mold. Propagation of bacteria and mold in such components can lead to unpleasant odors. This cleaning fluid in mist form removes dust from pipes and evaporators.

The product applies a liquid agent combining organic antifungal agents and inorganic antibacterial agents as a mist, enabling the antibacterial components to spread all across the evaporator. In addition, the organic antibacterial agents have an immediate effect, while the inorganic antibacterial agents are long lasting, providing a long-term odor-reducing effect after treatment. (Figures 3 and 4)

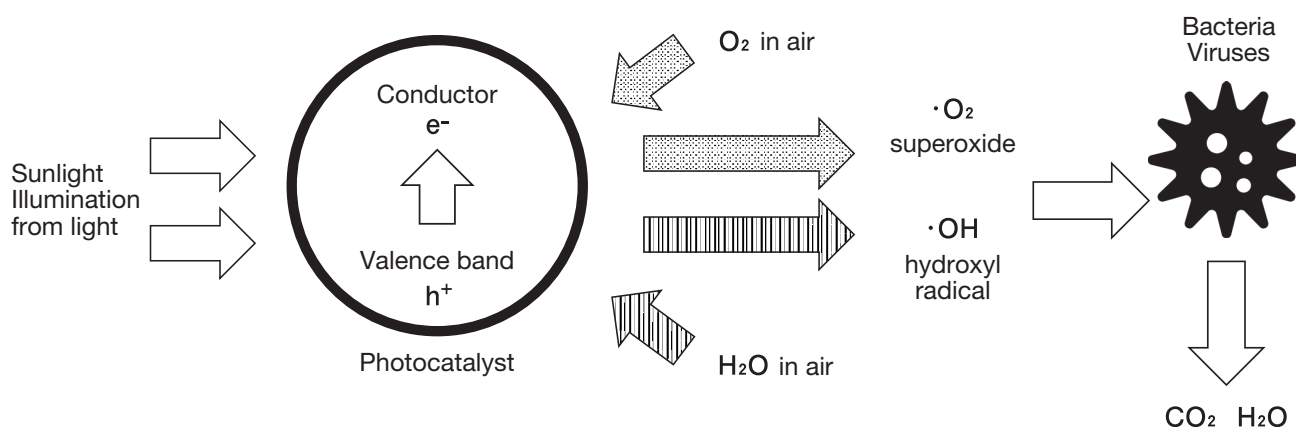
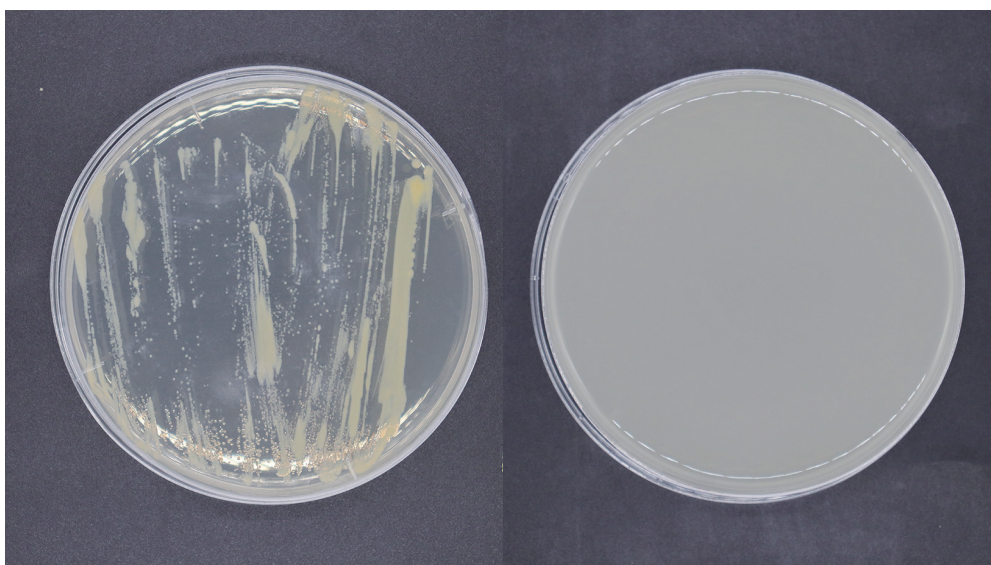


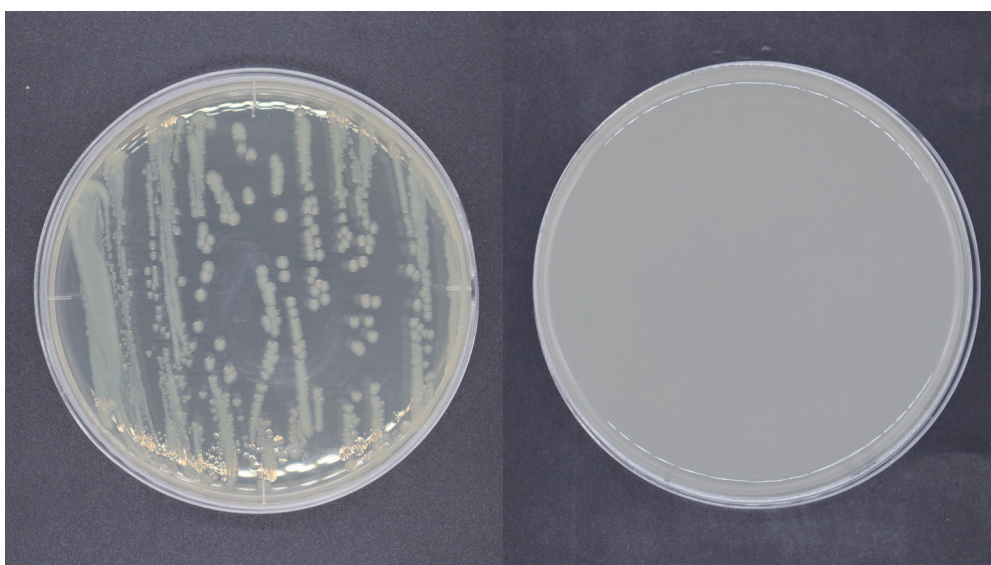
Fig. 2 Photocatalyst Antibacterial Mechanism<sup>2) 6) 7) 8)</sup>

The product also offers high safety because it uses a liquid agent and propellant gas that are non-flammable and non-hazardous. A comparison of a medium to which TB6721P had been added and an untreated medium

showed a reduction in bacterial colonies, which are clusters of bacteria, for both bacteria A and bacteria B. This confirms its antibacterial effects. (Figure 3)



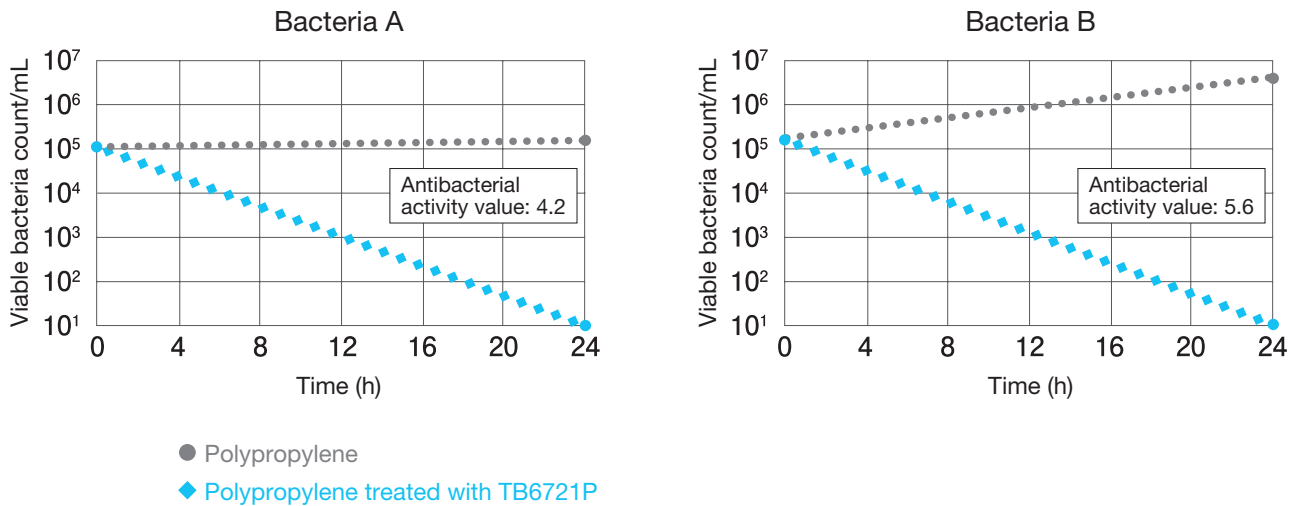
Bacteria A



Bacteria B

**Test conditions**  
Medium Left: Normal agar medium (sterilized: 20 mL)  
Right: Normal agar medium (sterilized: 20 mL) + TB6721P (1 mL)  
Cultivation conditions: 25°C · 24 h<sup>9</sup>  
\* TB6721P is a milky white liquid, causing the medium to turn white when added.  
White frame on petri dish is due to light during photography.

**Fig. 3 TB6721P Antibacterial Test**



**Fig. 4 TB6721P Antibacterial Test Results**

**\* Effectiveness against all bacteria is not guaranteed.**

**Value measured after 24 hours for test piece treated with TB6721P is detection limit value.**

**Fig. 4 Test Conditions**

3TS-9600-001 (JIS Z 2801) compliant

- Test bacteria: 2 types of bacteria (bacteria A and bacteria B)
- Bacterial fluid: Test bacteria suspended in 1/500 nutrient broth medium (105/mL)
- Test piece: 5 cm × 5 cm specimen

- (1) Polypropylene board treated with TB6721P
- (2) Untreated polypropylene board

- Bacterial fluid inoculation: Covered securely with film after test piece surface inoculated with bacterial fluid
- Test piece cultivation: Test piece inoculated with bacterial fluid cultivated at 35°C, and relative humidity of 90% or more for 24 hours
- Viable bacteria count measurement: Measurement of viable bacteria count performed on each test piece (n = 3) immediately after inoculation of test subject (performed untreated only) and after 24 hours of cultivation
- Antibacterial activity value (R) calculation:

$$R = \log_{10}U - \log_{10}A$$

U: Viable bacteria count on untreated test piece after 24 hours

A: Viable bacteria count on test piece treated with TB6721P after 24 hours

- Judgment criteria: Judged as effective if antibacterial activity value is 2.0 or higher

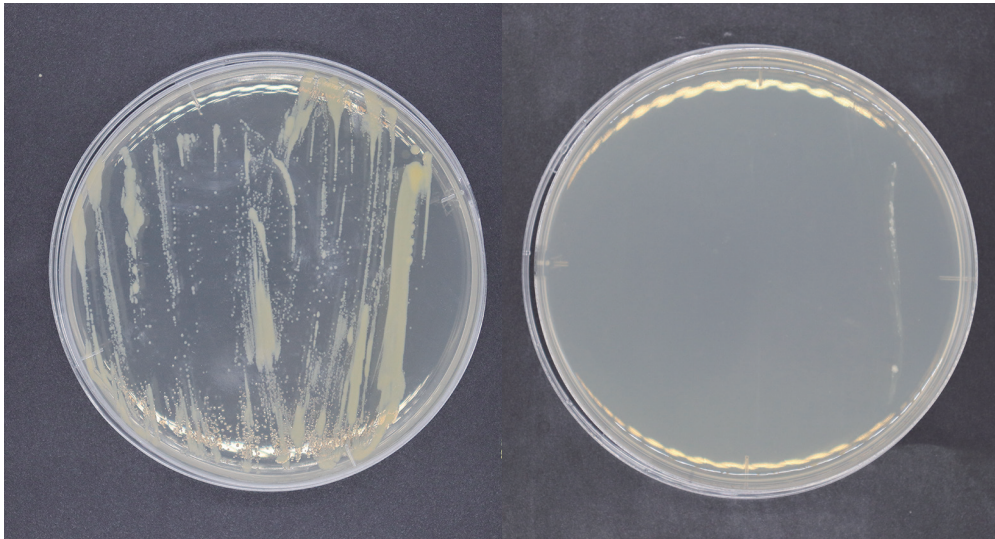
TB6721P has an antibacterial activity value of 2.0 or higher for both bacteria A and bacteria B, confirming that it has antibacterial properties against both types. (Figure 4)

**4-2 TB6735**

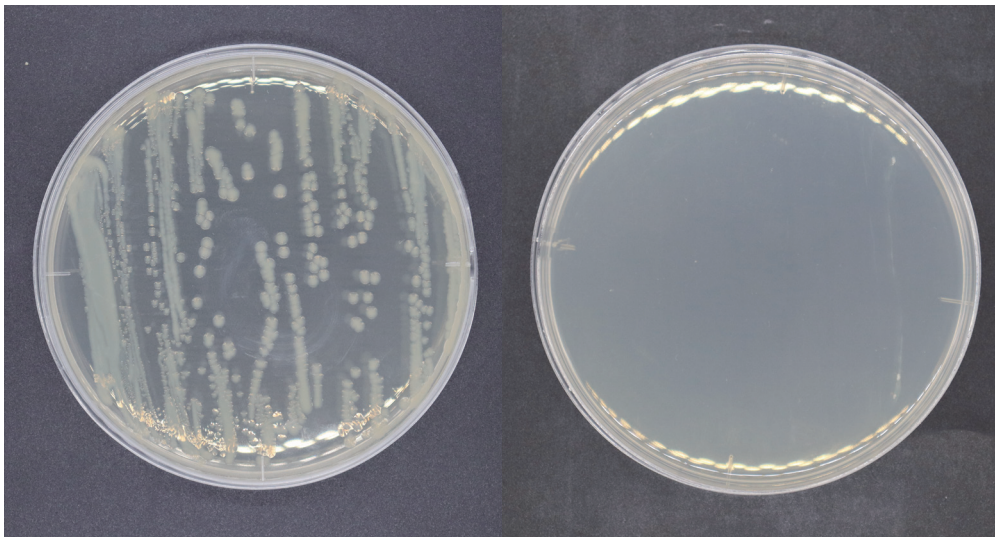
TB6735 is a visible light responsive photocatalyst spray that has been commercialized for use in automobile interiors. The full quantity of liquid agent is sprayed as a mist with a single push, making it easy to apply treatment evenly across the entire interior.

The UV ray-blocking effectiveness of automobile windows has improved in recent years, and this product can act using light sources such as interior cabin lights and LED lights in addition to UV rays. It displays antibacterial properties by using tungsten oxide, which responds to visible light, as a photocatalyst (Figure 5) and limits unpleasant odors caused by bacteria.

A comparison of a medium to which TB6735 had been added and a medium without added TB6735 showed a reduction in bacterial colonies, which are clusters of bacteria, for both bacteria A and bacteria B. This confirms its antibacterial effects. (Figure 5)



Bacteria A



Bacteria B

**Test conditions**

Medium Left: Normal agar medium (sterilized: 20 mL)

Right: Normal agar medium (sterilized: 20 mL) + TB6735 (1 mL)

Cultivation conditions: 25°C · 24 h

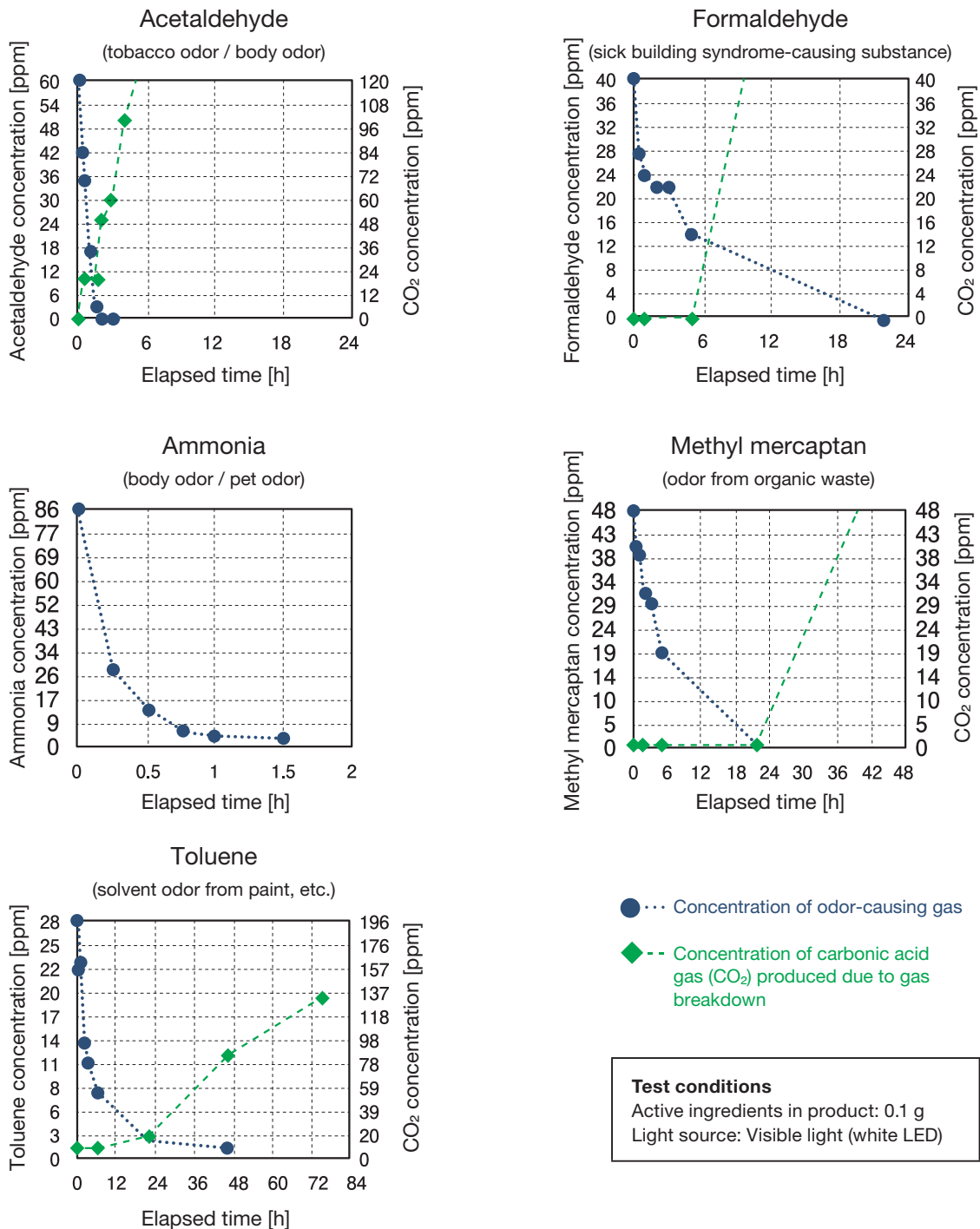
Light source: Visible light (white LED)

\* White frame on petri dish is due to light during photography.

**Fig. 5 TB6735 Antibacterial Test**

In addition to automobile interiors, this product can be used in spaces such as public transportation and homes, and can decompose substances such as gases that cause odors related to pets and organic waste (Figure 6) while also providing antibacterial properties. Under the test conditions shown in the diagram, changes in gas concentration in bags filled with various gases were measured over time.

The blue lines show the concentration of odor-causing gas and the green lines show the concentration of carbonic acid gas (CO<sub>2</sub>) released due to each gas being decomposed. High decomposition performance for various gases was confirmed. (Figure 6)



**Fig. 6 Gas Decomposition Performance Test**

\* Ammonia (NH<sub>3</sub>) does not contain carbon (C), meaning carbon dioxide (CO<sub>2</sub>) is not produced, even when broken down.

## Closing

In this article, the authors described microorganisms and antibacterial agents and introduced antibacterial products by ThreeBond. TB6721P and TB6735 are products that continue to maintain the cleanliness of automobile interiors, enabling people to enjoy cars in greater comfort.

ThreeBond will continue to develop antibacterial products that can be used in a wide range of settings, including automobile interiors, promoting lifestyles with cleanliness while contributing to sustainable industry and social and environmental conservation.

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