

# Development of Outdoor Mosquito Repellent Device STRONTEC® KA · KO · I

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The STRONTEC® KA · KO · I is an insecticidal device to provide an excellent mosquito repellency in outdoor spaces. It is the first and innovative product in Japan to be approved to quasi-drug as a pest control device using ultrasonic atomization. The device has a compact and easy-to-carry design which is suitable for mosquito repellent product for outdoor spaces. It delivers the active ingredient, Eminence® by periodical atomization process to produce solid and sustained special repellency. This paper introduces the STRONTEC® KA · KO · I repellent device by presenting its successful history of Research & Development as well as the product performances.

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## Introduction

STRONTEC® KA · KO · I is an insecticidal device having the effect/efficacy to repel mosquitoes in an outdoor space (approved as a quasi-drug on October 12, 2017). It is the sanitary insect pest control product using the ultrasonic atomization technology, whose manufacture and sales have been approved as a quasi-drug for the first time in Japan.

The concept for this product was to develop a compact “mosquito-repellent device for outdoor space” that could be easily carried around by anyone and provide a mosquito-free outdoor space for consumers to enjoy outdoor activities such as grilling and gardening.

In order to realize this concept, we developed a device that automatically atomizes the pesticide formulations containing Eminence® (Metofluthrin, SumiOne®), which is developed by Sumitomo Chemical as an insecticidal active ingredient that shows strong mosquito repellency at regular intervals, using the ultrasonic atomization technology that can atomize the active ingredient with lower power consumption (Fig. 1). Because this product atomizes the active ingredient at regular intervals, it can continuously and steadily provide mosquito-free space. Moreover, by combining the ultrasonic atomization technology (which efficiently atomizes the solution) with Eminence® (which demon-



Fig. 1 STRONTEC® KA · KO · I

strates strong mosquito repellency) we have successfully developed an easy-to-carry, battery-operated device. A single unit of this product can create a mosquito-free space with a radius of 3.6 m (40 m<sup>2</sup>).

Additionally, because a mosquito-free space can be created with a single operation of actuating the power switch, none of the other procedures required for other insecticides (e.g., applying the agent directly onto the skin or spraying it on the ground) are necessary. Thus, the application of this product is simple and easy. Moreover, it doesn't require fire or heat because it uses ultrasound for atomization. It won't therefore produce smoke, thus enabling its outdoor use for a variety of purposes (Fig. 2).



**Fig. 2** Application of STRONTEC® KA · KO · I

Under this development concept, this product is an insect pest control device that uses the ultrasonic atomization technique, whose manufacture and sale have been approved as a quasi-drug by the Ministry of Health, Labour and Welfare for the first time in Japan. This paper reports the results of the comparison between STRONTEC® KA · KO · I (whose manufacture and sale have been approved as a novel quasi-drug for outdoor use) to similar agents that have already been approved, the primary technological elements and operational suitability test as well as its safety.

### Comparing STRONTEC® KA · KO · I with Existing Similar Agents<sup>1)</sup>

The concept behind this product was to develop a portable and compact “mosquito-repellent device for outdoor use” that could be easily carried around by anyone. However, the mosquito repellents that have evolved have generally focused on preventing and exterminating mosquitoes at home, such as mosquito coils, electric mosquito repellents (mat type, liquid type), and fan- and aerosol-type repellents. Most of such products have evolved as mosquito repellents for indoor use, and there have been certain limits in developing repellents for outdoor use.

The manufacturing method for mosquito coils is as follows: The active ingredients (such as pyrethroid) are mixed with the plant constituents such as wood flour. Binding agents such as Machilus powder and starch are then mixed into said mixture. This mixture is made into

a sheet using an extruding machine, and then dried and shaped with a mold to obtain the final product. The temperature of the burning section of mosquito coils can reach 700°C to 800°C. However, the active ingredients will be volatilized at the area having the temperature of approximately 250°C at 6 mm to 8 mm before the burning section. Mosquito coils can volatilize the active ingredients into the atmosphere during the seven to eight overnight hours in which people sleep, maintaining a constant insecticidal effect. However, this type of repellent requires burning. Additionally, because it generates smoke and odor during the burning process, some consumers prefer other types of repellents.

Electric mosquito-repellent mats work as follows: pesticide formulation containing the active ingredients is absorbed into a fibrous mat. This mat is placed on the electric heating element and is heated to volatilize the active ingredients. Because it doesn't generate any smoke, it is suitable for those who want to avoid smoke or for the use in a room when windows must be kept closed. However, there is an issue in this repellent type that it is difficult to keep the amount of volatilized active ingredients chronologically consistent from the beginning to the end of the use. Contrary to this, as for a liquid mosquito repellent, a liquid-absorbent wick is dipped into the solution containing the active ingredients and then the top part of the wick is heated to volatilize the chemical solution. It can chronologically maintain the amount of volatilized active ingredients consistent. Also, once the chemical solution cartridge has been attached to the device, it can be used for a long time without

being replaced. However, because it's necessary to volatilize the active ingredients by electrically heating the active ingredients in any types of electric mosquito repellents, it requires rather large amount of electricity. Therefore, any types of electric mosquito repellents need a household power supply, and it is therefore not suitable for any use that requires portability.

A fan-type mosquito repellent works as follows: Active ingredients having a rather high vapor pressure are absorbed into various liquid impregnated materials. The active ingredients are then volatilized by air flow from a rotating fan or a supporter. Because this type of repellent can keep working with a dry cell battery for a long time, it can be used outdoors. (For example, a user can hang it by his/her side for portable use.) However, because the active ingredients are volatilized by means of an air flow at the ambient temperature, there is a limit in the volume of volatilized active ingredients, thus limiting the effective area in an outdoor space.

An aerosol-type mosquito repellent works as follows: Fine particles of pesticide formulation containing the active ingredients are sprayed using high-pressure gas. Because volatilization allows the active ingredients to diffuse, various ingredients can be sprayed at once and the spray volume can be freely adjusted. However, flammable contents are often contained in a propellant in aerosol repellents. Thus, it's necessary to take sufficient precautions to avoid risks of ignition or explosion and follow the regulation for disposal of propellants as well. Additionally, outdoor use of this type of repellent is restricted when the use of fire is involved in the activity (such as when grilling).

STRONTEC® KA · KO · I has solved all of the above issues in conventional mosquito repellents by adopting the ultrasonic atomization technology in an atomization device. The primary technological elements of this novel product will be explained in the next section.

## Primary Technological Elements

### 1. Active Ingredient Eminence® (Metofluthrin, SumiOne®)<sup>2)</sup>

The active ingredient of this product, Eminence®, is a synthetic-pyrethroid base insecticide that shows strong insecticidal and repellent effects against mosquitoes. Eminence® is the insecticidal active ingredient, and it was explored as a synthetic pyrethroid having an excellent transpiration and innovative efficacy.

The active ingredient of Eminence® is a fine-yellow,

clear, oily liquid. Although it's soluble to most organic solvents, it's insoluble in water. The vapor pressure at 25°C is  $1.96 \times 10^{-3}$  Pa, showing a relatively high vapor pressure as a pyrethroid base insecticide. Its kinetic viscosity is 19.3 mm<sup>2</sup>/s (20°C), and it's easy to handle in terms of liquid property.

Next, **Table 1** depicts the lethal activity (topical application) of Eminence® against mosquitoes.

**Table 1** Lethal efficacy against mosquito

Compound	<i>Culex pipiens</i>	<i>Aedes albopictus</i>
Metofluthrin (Eminence®)	0.0015	0.00047
d-allethrin	0.038	0.023
Prallethrin	0.0056	0.0050
d-tetramethrin	0.0096	0.0036
Permethrin	0.0028	0.0012

LD<sub>50</sub> (µg/female adult) by topical application method

The LD<sub>50</sub> value of Eminence® against adult *Culex pipiens pallens* is 0.0015 µg/female, showing the relative insecticidal activity of approximately 25 times and four times greater than that of d-allethrin and prallethrin, respectively. Additionally, it shows said activity about twice as strong as that of permethrin, which is a typical insecticide having a high insecticidal activity.

The LD<sub>50</sub> value of Eminence® against adult *Aedes albopictus* is 0.00047 µg/female, showing the relative efficacy of approximately 50 times, 10 times and four times higher than that of d-allethrin, prallethrin and permethrin, respectively.

Because atmosphere constantly changes in an outdoor space, it's difficult to maintain the consistent concentration of the active ingredient in the atmosphere. Therefore, in order to allow the product to show sufficient efficacy even in an outdoor space, we have adopted Eminence® that shows high insecticidal performance against mosquitoes.

## 2. Atomization Using Ultrasound

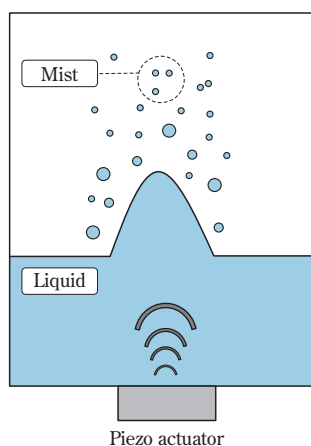
### (1) Atomization Using Ultrasound<sup>3), 4)</sup>

Ultrasound is defined as sound waves with frequencies of 20 kHz or higher, which exceeds the upper audible limit of human hearing. It not only propagates in the atmosphere, but also propagates in or on the solid and liquid matters, or along with the boundary of two different solid or liquid matters. Ultrasound is widely used in modern human society. Not only is it used in the atomization technique for this product, but it is also used in

a variety of areas such as cleaning, emulsion dispersion, welding, detectors such as sonar, and medical care/diagnosis/treatment.

Ultrasonic atomization can be achieved by radiating strong ultrasonic waves to the target liquid. When a large amount of energy exceeding a certain level concentrates on the liquid surface, it exceeds the amplitude threshold, thus fracturing the liquid surface and generating droplets. Once the ultrasonic vibration becomes vigorous in the liquid, it causes an ascending flow on the liquid which is present directly above the ultrasonic vibrator, pushing the liquid surface upwards, thus generating a liquid column. On the surface of this liquid column if energy produced when the droplets collide and tear each other off overpowers the surface tension of the liquid, the liquid will turn into fine particles and scatter into the atmosphere (Fig. 3).

STRONTEC® KA · KO · I utilizes this ultrasonic atomization technology to atomize the active ingredient.



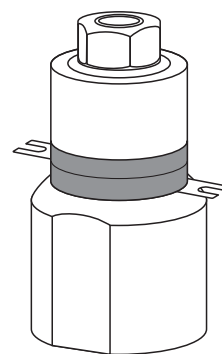
**Fig. 3** Principle of ultrasonic atomization

## (2) Selection of Atomization Using a Vibration Plate

It has been known that there are various forms of ultrasonic atomization. Generally, the vibration method (in which a piezo actuator shown in Fig. 3 is caused to vibrate in the liquid to be atomized) is widely used for humidifiers and nebulizers. Although this method has the advantage that particles are extremely small and highly uniform, it usually requires ultrasonic waves with MHz frequencies. Due to its poor atomization efficiency, it's difficult to generate a large amount of mist with low electrical power.

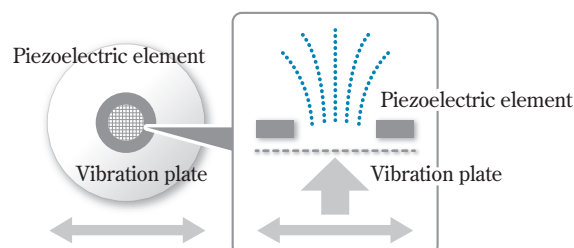
Additionally, the Langevin-type transducer fastened by a bolt, which was invented in 1917 by the French physician Paul Langevin<sup>5)</sup> (Fig. 4), has been known as

a conventional ultrasonic atomization device using a piezoelectric element. Although this transducer has an advantage that it can atomize liquid using the low-frequency ultrasonic waves of several tens of kHz, showing an excellent efficiency, it also has a shortcoming that its structure is complex, and thus it must be polished when used with an object where a large vibratory stress can be generated such as a piezoelectric element and a metal block.



**Fig. 4** Langevin type transducer

However, for the atomization of this product, the method that utilizes an ultrasonic vibration unit (which is created by laminating a vibration plate that has numerous small holes to the ring-shape piezoelectric element) has been adopted (Fig. 5). As described in the reference document 6) (Japanese Patent Disclosure, Heisei No. 4-371273), this ultrasonic vibration unit can atomize liquid with ultrasonic waves at a frequency ranging from several hundred kHz, thereby showing excellent efficiency. It can therefore generate a large amount of mist with low electric power. Additionally, it has another advantage that it has a less complicated structure as compared to the Langevin type transducer.<sup>6)</sup>



**Fig. 5** Mesh plate type transducer

Adopting the vibration-plate type ultrasonic vibration unit enabled us to achieve the ultrasonic atomization that utilizes a battery as a driving force, rather than a



household power supply. This allowed us to realize our development concept of this product: being able to carry around easily.

### 3. Special Features of STRONTEC® KA · KO · I

#### (1) Product Specifications

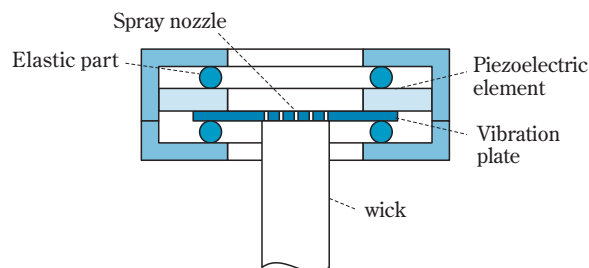
STRONTEC® KA · KO · I automatically sprays pesticide formulation containing 0.403 w/v% of active ingredient Eminence® every 30 seconds by atomizing the solution into particles (the average particle size of approximately 20 μm) to outdoor space through the ultrasonic atomization technique. One unit of this product alone can provide mosquito-free space with a radius of 3.6 m (40 m<sup>2</sup>). This product is an atomizer having a truncated cone shape with the dimension of approximately 10 cm in length, width and height, respectively. It has an ultrasonic vibration unit (vibration plate) on the top panel. Using a vibration-plate type vibration unit has enabled uptime of approximately 60 hours with two AA alkaline batteries as the power source. Additionally, a replaceable cartridge filled with 60 mL of the pesticide formulation is attached to the product. A single chemical solution cartridge lasts approximately 30 hours (Table 2). The auto-off function has been added as well, in order to prevent the solution to be wasted when the product was accidentally left on. This function automatically turns off the switch five hours after the product is turned on.

**Table 2** General description of STRONTEC® KA · KO · I

Application	Outdoor mosquito repellent (40 m <sup>2</sup> )
Active Ingredient	Metofluthrin 0.403 w/v % (Eminence®/SumiOne®)
Other inert	Kerosene
Net volume	60 mL
<b>Device</b>	
Particle size of spray	Approximately 20 μm
Spray interval	30 seconds/spray
Duration per cartridge	Approximately 30 hr
Dimension	Width 11.2 cm × Height 10.5 cm
Power supply	Two AA batteries

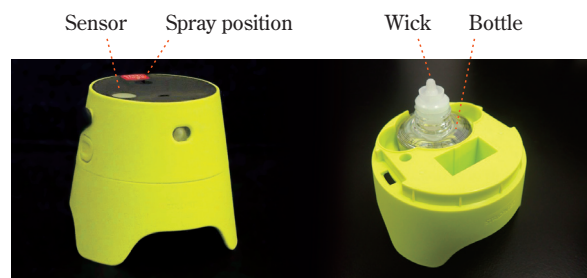
The pesticide formulation in the cartridge is supplied through the liquid-absorbent wick. The liquid-absorbent wick extends from the cartridge, coming into the contact with the vibration plate in the ultrasonic atomization unit, and the pesticide formulation oozes out through small holes on the vibration plate.

When atomizing the pesticide formulation, the vibration plate is vibrated at high speed by electrifying the piezoelectric element that is laminated to the vibration plate, and the oozed-out solution is then flicked out into the atmosphere (Fig. 6).



**Fig. 6** Structure of atomizing part

The atomizer has two separate parts: the upper cover part and the lower part. The upper cover part contains an ultrasonic atomization unit, a base plate and other components, and the lower part has a section where a chemical solution cartridge is housed. The product has been designed in such a way that once the chemical solution cartridge is set, the liquid-absorbent wick will naturally come into contact with the vibration plate merely by coupling two parts together. Thus, the pesticide formulation is atomized without any complex operations by consumers (Fig. 7).



**Fig. 7** Device configuration

Moreover, because it has been designed to atomize the pesticide formulation at regular intervals, it has a mechanism whereby a LED lamp placed near the switch would begin blinking approximately five seconds prior to atomization to warn consumers, so that they won't be directly exposed to the chemical solution mists by accident. The LED lamp blinks 9 times until the device starts to spray mists. Additionally, as a safety measure the device is equipped with a motion sensor so that it will automatically stop spraying if the sensor detects

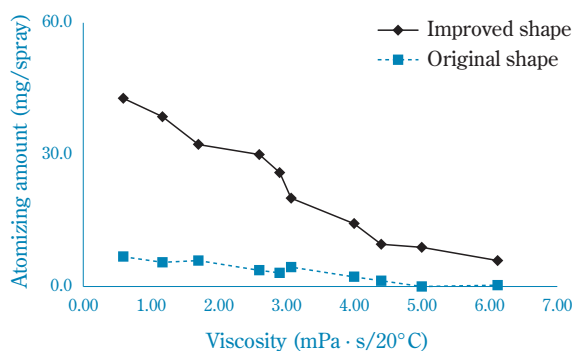
human motions above the main unit (the sensing range varies depending on the human motions and the body temperature).

## (2) Itemized Discussion on Technical Elements

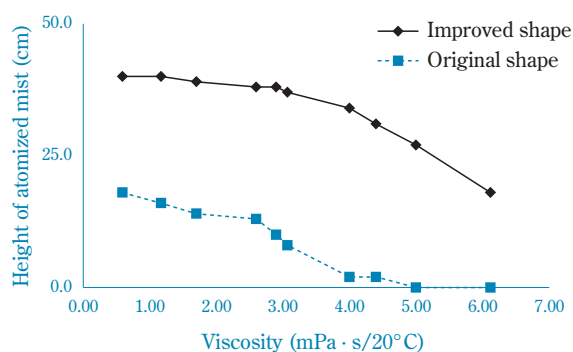
### (i) Optimization of Ultrasonic Vibration Unit

Because this product repels mosquitoes in an outdoor space with the widest possible range, it is ideal to have a design that enables it to efficiently atomize pesticide formulation containing the active ingredient as high and far as possible. Increasing the voltage to be applied to the ultrasonic vibration unit or using a ventilation fan is commonly used to achieve these goals. However, these countermeasures have some issues such as that it enlarges the size of the device. Therefore, we have optimized the configuration of the vibration plate used for the ultrasonic vibration unit of STRONTEC® KA · KO · I in order to achieve more efficient atomization.

As a result of our investigation, as shown in **Fig. 8** and **Fig. 9**, it has been revealed that comparing to the vibration plate having the conventional configuration, the vibration plate with the optimized configuration increased the volume of atomized chemical solution as well as the height of atomization, thereby increasing the



**Fig. 8** Atomizing amount as a function of viscosity of improved shape vibration plate



**Fig. 9** Atomizing height as a function of viscosity of improved shape vibration plate

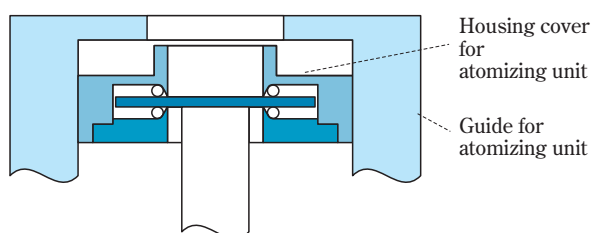
diffusion of the chemical solution, particularly in the low-viscosity zone.<sup>7)</sup> In order to achieve the adequate atomization efficiency for STRONTEC® KA · KO · I, we have adopted the solvent with rather low viscosity. Also, when assembling an ultrasonic transducer (composed of a piezoelectric element laminated to a vibration plate having small holes) to the atomizer's main body, the elastic component is commonly used to secure it. In this product as well, the ultrasonic vibration unit is assembled to the atomizer's main body using an elastic component. However, as a result of our examination conducted upon developing this product, we have discovered that the contact area between the elastic component and the piezoelectric element would affect the atomization efficiency. We have therefore adopted a structure that supports the ultrasonic vibration unit using an elastic component, in order to achieve more efficient atomization.<sup>8)</sup>

### (ii) Optimization of the Liquid Feeding Mechanism

Because this product expels mosquitoes outdoors, covering as wide space as possible, it is desirable to design the device in a way that a relatively large amount of pesticide formulation can be atomized at a time. The volume of atomized pesticide formulation can be adjusted by adjusting the time to apply voltage to the ultrasonic transducer and other means. This can be done only if adequate amount of pesticide formulation is supplied to the ultrasound vibration unit. In this product the solution is fed to the ultrasonic vibration unit through a liquid-absorbent wick. Considering the convenience in using the device, it is ideal to minimize the size of the ultrasonic vibration unit. However, if the size of the ultrasonic vibration unit is reduced, it becomes necessary to reduce the size of the liquid-absorbent wick as well. In order to obtain an adequate atomization volume in an outdoor space, it is necessary to use a soft, porous material for the liquid-absorbent wick.

On the other hand, because STRONTEC® KA · KO · I uses a replaceable chemical solution cartridge and a liquid-absorbent wick, consumers must assemble them to the atomizer by themselves. The atomization method we adopted for this product had some issues due to the softness of the liquid-absorbent wick. Because said wick must be sufficiently contacting the vibration plate, if a material used for a liquid-absorbent wick is soft, poor atomization may occur due to the squashed or deformed wick. We have therefore created a cylindrical guide that can slide only vertically right above the liquid-absorbent

wick, so that the surface of the ultrasonic vibration unit can come into contact with the tip of the liquid-absorbent wick automatically by its own weight. This has enabled the device to maintain the stable contact status between the ultrasonic vibration unit and the liquid-absorbent wick, even though the wick is crushed or deformed slightly when replacing the solution cartridge.<sup>9)</sup> (Fig. 10)



**Fig. 10** Contact structure between wick and vibration plate

Additionally, we also thought out the structure of the liquid-absorbent wick. By placing a porous absorbent at the tip of the liquid-absorbent wick, we have improved the stability of the area where the vibration plate comes into contact with the liquid-absorbent wick. The feeding capability of the liquid-absorbent wick has also been improved due to the liquid-retention feature of the absorbent itself.<sup>10)</sup> Moreover, we have improved the pesticide formulation in the cartridge and the fresh air ventilation structure. The pesticide formulation is fed through the liquid-absorbent wick in the same manner used in the standard liquid-type electric mosquito repellent.

Generally, in the liquid cartridge with a liquid-absorbent wick, it is assumed that the opening of the liquid cartridge coheres to the liquid-absorbent wick. If the cartridge doesn't have any ventilation system, there is an issue that the environment in the cartridge may become unstable, such that the internal pressure of the cartridge decreases in accompany with consumption of the liquid, or that the internal pressure excessively increases due to the increase in the temperature. Therefore, in this type of repellent devices an air vent is often created in the upper part of the pesticide formulation cartridge. For this product, we have also created an air vent in the upper part of the cartridge.

However, because this product needs to atomize a relatively large volume of pesticide formulation at a single atomization, the diameter of the required air vent must be naturally large. This can cause the issue that the pes-

ticide formulation would leak out from this large air vent when the cartridge toppled sideways. We therefore designed special shaped inner plugs and created a structure that could reduce the risk of leakage of the solution by automatically closing the air vent of the solution when the cartridge has toppled sideways.<sup>11)</sup>

These structural improvements have made possible the solution-feeding mechanism that can atomize a relatively large volume of pesticide formulation at a single atomization while using a compact, liquid-absorbent wick.

#### 4. Controlling Volatilization of Active Ingredient in Outdoor Space

Generally, volatilization of the active ingredient in indoor space is controlled to maintain the concentration of the active ingredient, so that it won't go below the level at which it shows its efficacy against target insects in indoor space. It is assumed that the active ingredient's concentration level goes down by ventilation. According to the technical standards for the ventilation system for living space stipulated by the Building Standards Act, the index for effective ventilation in a room ( $\text{m}^3/\text{h}$ ) is defined as follows: The effective ventilation in living space when using a mechanical ventilation system such as a ventilation fan is 20 per person in the room ( $\text{m}^3/\text{h} \cdot \text{person}$ ) (Enforcement Order Article 20, Paragraph 2). When designing a device for spraying the active ingredient in the indoor ambient air, it is necessary to add a function through which the speed of spraying the active ingredient can be adjusted to suite the application purpose, using the effective ventilation volume as a parameter, so that the active ingredient's concentration level can be maintained consistent in the room.

We, however, assumed that unlike the case of indoor use, the concept of the effective ventilation was not applicable to the use in an outdoor space because it would be affected by the forced convection generated by wind, thus hindering the ability of gas to linger in the space. Therefore, we studied the atomization method that would most effectively demonstrate mosquito repellency in an outdoor space, we realized that the particle size of the pesticide formulation, active ingredient's concentration level and atomization interval affect the mosquito-repellent effect in an outdoor space.<sup>12)</sup> It has been surmised that in an outdoor space if the particle size of the atomized chemical solution is too small, even if the required amount of active ingredient is atomized, the solution particles would be diffused excessively due to

the forced convection generated by wind, and that the solution concentration and atomization interval affect the opportunity of the target insect to come into contact with the active ingredient.

Based on these studies, for this product, we have adopted the particle size of the pesticide formulation and the atomization method that can effectively repel mosquitoes in an outdoor space.

## 5. Human Motion Sensor

Additionally, due to the feature of the product specifications, which is that it atomizes the pesticide formulation at regular intervals, we have equipped the product with a pyroelectric infrared sensor in consideration of the safety of the product to prevent consumers from being directly exposed to the pesticide formulation mists. Pyroelectric infrared sensors are widely used in a variety of areas such as lighting fixtures and surveillance cameras to detect if anybody has invaded or moved from one place to another, covering a relatively wide area. This sensor uses the phenomenon that a temperature change changes the dielectric polarization (the pyroelectric effect) and detects the temperature difference (movement) between the target and surroundings.

With regards to the sensor selection, it must be inexpensive and have a compact and simple structure that is appropriate for the product characteristics. Considering the product's application purpose, the following sensor types were considered applicable: luminance sensor; pyroelectric infrared sensor; reflective sensor; and a projected-image sensor system. However, it was concerned that malfunctions could occur often in the most inexpensive sensor, which was a luminance sensor, because it could be affected by shadows from objects and clouds and operation during the nighttime. Regarding a reflective sensor and a projection-type sensor system, although they have an excellent accuracy, the system could be complicated. Based on these factors, we decided to adopt a ceramic infrared sensor, considering the cost and power consumption as well.

## 6. Main Body Design with Optimized Usability

Perhaps because no other similar products are available in the market, many consumers have pointed out problems on the product operability, such as, "I'm not sure how to replace the chemical solution cartridge" or "It's difficult to find the switch" during a consumer test conducted in the prototype stage. Therefore, in the productization stage we carefully inspected the design

through an internal questionnaire survey and other similar means, keeping in our mind to make it easy for consumers to operate the device.

Additionally, from the perspective that the product uses a pesticide formulation, we designed the product with due care to safety. Because the product will be used outdoors, harsh application conditions—such that the device may topple sideways or dropped from a high place—were assumed. Therefore, we designed the product giving sufficient consideration to the risk of chemical solution leakage as well as the durability that can endure such a harsh environment of application.

Additionally, it was necessary to pay careful attention when designing the device from the perspective of outdoor applications. The following is a specific example: Because this product is used outdoors in midsummer, the temperature of the ground where the atomizer is placed can occasionally exceed 50°C. At the initial design stage, we planned to use PET materials having outstanding processability for a chemical solution cartridge. However, PET materials can swell and deform in the environment where the temperature exceeds 50°C. Therefore, we selected the heat-resistant PET grade, keeping in mind the severe environment of outdoor use.

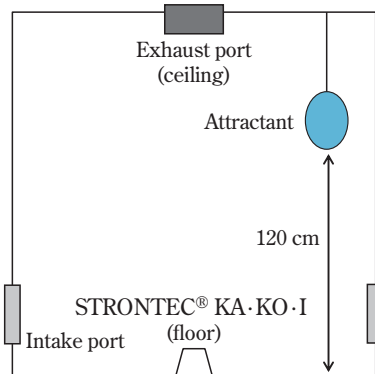
## Operational Suitability Test

### 1. Evaluation of Basic Efficacy

This product STRONTEC® KA · KO · I is designed for outdoor use. First, we tested its basic efficacy against mosquitoes through an indoor test using a chamber. An attractant was placed in a Peet-Grady chamber<sup>13)</sup> with a ventilation system and STRONTEC® KA · KO · I in operation (Fig. 11). Immediately after this procedure, approximately 50 adult female *Aedes albopictus* or adult female *Culex pipiens pallens* were released in the chamber. Mosquitoes were retrieved three hours later and the level of fixation to the attractant was checked and the attraction rate (%) was calculated. While the attraction rates of *Aedes albopictus* and *Culex pipiens pallens* were 45.6% and 87.0%, respectively, in the non-treated area, when the product was in operation, the attraction rate was 0% for both mosquito species, meaning that no mosquito was attracted (Table 3). The active ingredient of this product, which is the pyrethroid insecticide Emence®, not only demonstrates insecticidal efficacy against various types of insect pests, but also shows the outstanding so-called "knockdown effect," which quickly paralyzes insect pests and prevents them from feeding



on the blood.<sup>2)</sup> It was surmised that in this test the blood-feeding behavior of adult female *Aedes albopictus* or adult female *Culex pipiens pallens* released in the Peet-Grady chamber was hindered extremely quickly after their being exposed to Eminence® in the air. Additionally, based on the fact that the product showed a high efficacy in the test while ventilating the air in the chamber, it can be expected that it will also show high efficacy during actual outdoor use.



**Fig. 11** Test method in Peet-Grady chamber

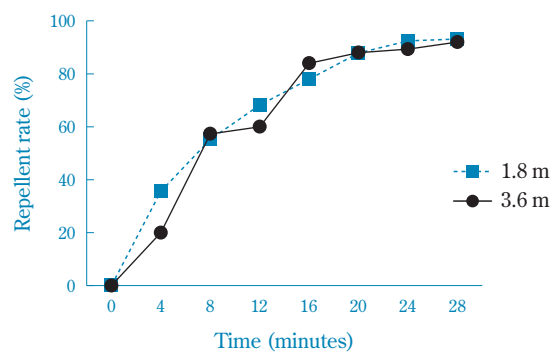
**Table 3** Test results of efficacy test in Peet-Grady chamber

	Attracted rate (%)	
	<i>Aedes albopictus</i>	<i>Culex pipiens pallens</i>
KA · KO · I	0	0
Blank	45.6	87

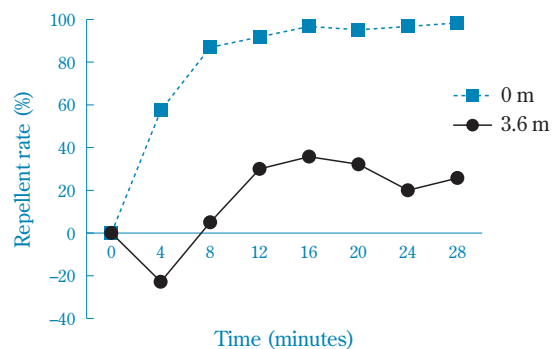
## 2. Evaluation of the Practical Effect

In order to specify the practical effect and effective area of STRONTEC® KA · KO · I, a field test was conducted. Because the test site was in the outdoor environment where a large number of *Aedes albopictus* and *Armigeres subalbatus* breed, the testers put on protective clothing, gloves and insect-proof net in order to avoid being bitten by mosquitoes. The tester who played the role as an attractant stood in a bush or at the edge of a wood, and the number of mosquitoes mooring on the surface of the protective clothing and flying around the protective clothing was counted. Once it was confirmed that the number of mosquitoes attracted to the attractant reached a certain level, the product was placed on the ground with a certain distance from the attractant, and then turned on. The wind direction was confirmed before turning on the device, and the device was tested repeatedly, each time in different positions of upwind, downwind and in the middle of upwind and downwind.

The repellent rate (%) was calculated from the number of attracted mosquitoes for each elapsed time. The result showed a high rate of repellence. When operated in a place 1.8 m and 3.6 m away from the attractant, for both places the repellent rate reached over 50% within 8 minutes and over 90% within 28 minutes (Fig. 12). The same test was conducted using a mosquito coil available in the market. Although the coil showed high repellent effect when positioned close to the attractant (at the foot of the attractant (0 m)), which is the similar application method as with STRONTEC® KA · KO · I (carried around by a user in a close range), when positioned in the area with more distance—3.6 m away from the attractant—it didn't show adequate repellent effect (Fig. 13).



**Fig. 12** Efficacy of STRONTEC® KA · KO · I in outdoor field



**Fig. 13** Efficacy of commercial mosquito coil in outdoor field

Based on these results, it can be surmised that by placing one unit of the product in a space having a radius of 3.6 m (40 m<sup>2</sup>), one can create a mosquito-repellent space. Also, it has been confirmed that under the same conditions, the efficacy of STRONTEC® KA · KO · I exceeds that of an outdoor mosquito coil currently available in the market.

Repellent rate (%) =  $(1 - T/C) \times 100$

T : The number of mosquitoes attracted n minutes after turning on the device (a total of three consecutive tests)

C : The number of mosquitoes attracted before turning on the device (a total of three consecutive tests)

## Safety of STRONTEC® KA · KO · I

The pesticide formulation used for this product contains 0.403 w/v% of the active ingredient Eminence®. The concentration of this active ingredient is nearly equivalent to that of the chemical solution used for liquid-type electrical mosquito repellents sold at the drugstores and the like. The safeness of this pesticide formulation has been confirmed in the market for a long time. Additionally, as a safety measure for atomization, we have added an LED lamp, which warns consumers immediately before atomization starts as well as a motion sensor that automatically stops atomization if human motion is detected above the main body of this product.

Additionally, as one of the precautions to take, we have instructed consumers to not use the product indoor where ventilation isn't sufficient because the volume of atomization has been set particularly for outdoor use.

## Conclusion

STRONTEC® KA · KO · I is the insect-repellent device using the ultrasonic atomization technology, whose manufacturing and sale have been approved as a quasi-drug for the first time in Japan. It is rare that manufacture and sale of such a novel active-ingredient delivery system is approved as a quasi-drug. We hope that the application of this novel active-ingredient delivery system will not be limited to this product, but it will be further expanded to the field of life environment.

Additionally, the mosquito repellency in an outdoor space has been approved as this product's effect/efficacy. Until then, conventional agents having the repellency against mosquitoes outdoors, whose manufacture and sale had been approved as a quasi-drug, have been limited to mosquito coils and aerosol products with the residual effect. However, this time we were able to obtain the approval for manufacture and sale of this

novel ultrasonic atomization device as a quasi-drug, which utilizes the intermittent atomization technology.

Demand in mosquito repellents for outdoor space is increasing not only in Japan, but also in overseas market. We believe that the delivery technology of this novel product STRONTEC® KA · KO · I can respond to such a large demand.

Because this product volatilizes the sufficient amount of the active ingredient Eminence®, which shows high efficacy (particularly against mosquitoes), it can be expected that it will be highly effective in actual outdoor use as well. Additionally, because it can be operated with dry cells, it's easy to carry around. Because it doesn't require fire or gas, it won't generate any smoke. Thus, consumers can readily create mosquito-repellent space outdoor. We developed product, keeping "solid efficacy" and "usability for consumers" in our minds at all times, and we hope that these concepts will be widely accepted by consumers.

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