Promotion of Hygiene at Evacuation Centers: Repelling Flies

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Abstract

The number of outbreaks of natural disasters in the world has been increasing over the last few decades. In addition, the hygienic environment after a disaster is one of the factors which has a decisive influence on the reconstruction of disaster-stricken towns. Therefore, the goal of this research is to improve the hygienic environment at evacuation centers and particularly to repel flies, one of the harmful insects. In this research, attention is paid to the smell of limonene because it has an aromatherapeutic effect as an aroma oil as well as a repellent effect on flies. In addition, the places where our measures will be taken were specifically chosen and the forms of our measures for practical use are considered, taking past disaster records into account. This research paper aims to contribute to the progress in the field of repelling flies, which is non-fully developed, and thus contribute to the promotion of hygiene at evacuation centers.

Keywords

Disaster, Flies, Repelling, Smell, Limonene, Embodiment

Background

Nowadays, natural disasters occur frequently in the world. According to *the Cabinet Office*, approximately 160 million people suffer from natural disasters each year, and about 100,000 people are deprived of their lives. The amount of damage is more than 40 billion dollars (average from 1970 to 2008 per year worldwide). Furthermore, looking at the last 10 years, the number of natural disasters and affected people has increased about three-fold from the 1970s. There has been a great discussion about measures against natural disasters. In addition, *World Risk Report 2016 Edition* notes that Japan ranks fourth in the frequency of natural disasters. Therefore, Japanese people, in particular, living in one of the most disaster-prone countries, have to take the initiative in the world to tackle this problem.

The damage from a disaster can be classified into two categories. One is direct damage such as the collapse of houses, which is called *primary damage,* and the other is incidental damage such as fire, gas leaks, the spreading of infectious diseases and the physical or emotional trouble of the victims, which is called *secondary damage*. Fire and gas leaks occur immediately after disasters, and the spread of diseases and physical or emotional troubles occur in the medium-to-long term after disasters. In addition to primary damages, secondary damages are also enormous. For example, in the Great Kanto Earthquake, which occurred in September 1923, 400 fires occurred in Tokyo and Yokohama after the earthquake, resulting in a large-scale fire. More than 100,000 people were killed in the earthquake and

its aftermath, 90% of whom were killed by fire. Prevention of secondary damages plays an important role in reconstruction of disaster-stricken towns. In other words, more attention should be given to taking measures against secondary damages.

It is important to take measures against harmful insects. Therefore, it is necessary to research how to develop countermeasures against harmful insects at the time of disaster, focusing mainly on flies. Among the harmful insects, flies are familiar and found everywhere. In addition, the harm caused by flies is great. For example, in the Great East Japan Earthquake, massive marine products leaked out in the coastal area due to earthquakes and tsunamis leading to a large outbreak of flies. The victims had difficulties in coping with the flies. Certain species of flies are very harmful and can carry viruses and bacteria. Moreover, quite a few people feel uncomfortable with flies and avoid contact with flies.

Purpose

The present study is undertaken in order to seek a way to solve the problem with harmful insects. The research question is as follows:

"Is it possible to repel flies easily at evacuation centers without using any special materials?"

Repelling is targeted in our research. A possible measure against flies should be one which can easily be used by all people. Exterminating flies is unsanitary because their dead bodies remain, causing an unsanitary situation especially at evacuation centers and other small places. Therefore, the goal is to repel flies. Each method of exterminating and repelling has its merits and demerits. Among papers published in *CiNii*, the Japanese website for academic papers, there are only 11 papers on repelling flies, while there are 128 papers on exterminating them. This means little study has been done concerning repelling flies. Therefore, it can be said that more research on repelling flies would be worthwhile in this field. The term "repellent effect" can be defined as a state where the number of insects gathering around something decreases compared to cases where no measures are taken.

Method

(1) Flies and the damage they cause that appear at the time of disaster

In this section, the kinds of flies are explained in connection with the situation at the time of disaster. There are many cases where outbreaks of flies have occurred. One representative case is the Great East Japan Earthquake. Several studies have shown that a large number of flies have bred when a disaster occurred. According to *Outbreak of Flies and Control of them in Tohoku Affected Areas*, flies which belong to the family *Calliphoridae* including *Calliphora nigribarbis* bred in rotten fish, and small fly species such as *Fucomyia frigida* and flies of *Sphaeroceridae* bred on the surface of debris composed of fishing nets, seaweed, waste materials and so on. Furthermore, according to the *Report on the Observation of the Flies in the Area Afflicted by the Great East Japan Earthquake*, although flies of *Anthomyiidae* and *Agromyzidae* were observed, the main species that were dangerous to people

because of large outbreaks were *Calliphora nigribarbis* and *Lucilia caesar* (mainly *Phormia regina*). In addition, the number of *Musca domestica flies*, which prefer vegetable food to fish meat, increased inside and outside buildings at evacuation sites. It is notable that flies of *Musca domestica* often intrude into a house, gather around food for humans, and stay around humans. Therefore, it is necessary to pay particular attention to insects which transport bacteria.

The characteristics of these flies are as follows:

1. They like sulfur compounds, and they gather around human feces, animal cadaver, kitchen waste, and so on. For example, flies of *Lucilia caesar* or *Calliphoridae* like rotten fish and shellfish, flies of *Musca domestica* and *Fannia canicularis* like organic matter such as grain feed and cow dung, and flies of *Boettcherisca peregrina* like carcasses of animals.
2. Female flies lay about 500 eggs in their lifetime, and the eggs hatch in about one day, pupate in a week, and develop to the adult stage in two weeks. This is a rapid breeding cycle.
3. The place of occurrence is mainly rubble, surroundings of fishery processing facilities, evacuation centers, clogging of drainage ditches and so on.
4. The time of outbreak is early summer and autumn. In midsummer, the number of flies slightly decreases.

Primarily two kinds of harm can be caused by flies, discomfort of appearance and spread of disease. Flies walk around dirty places and carry pathogenic bacteria on their feet and bodies. In addition, *Musca domestica* ingests protein sources from things such as animal excrement, carcasses, rotten food, and so on. This means there is a high risk of mediating bacteria. On the other hand, in terms of spreading bacterial infection, blood-sucking flies seem to present a lower risk. In addition, a lot of parasites and viruses breed in fly foods. It is known that flies infect people with diseases such as dysentery, cholera, typhus, polio, O-157 and more. Globally, there are also pathogens which flies specifically carry. For instance, *tsetse flies* cause African sleeping sickness, and flies of *Phlebotomus* cause leishmaniasis. These pathogens are not bacteria but protozoa.

(2) Existing measures against flies

There are various products to repel or exterminate flies. According to *Outbreak of Flies and Control of them in Tohoku Affected Areas*, it seems that the smallest and the most popular countermeasure at the time of a disaster was the PET bottle removal method. By drilling a hole in the upper part of a plastic bottle and pouring sugar (50 *g*), sake (70 *ml*), vinegar (100 *ml*) into the plastic bottle, it will become full of flies in one day. Large fly adhesive paper (commercially available) was also widely used. As large-scale measures, insecticide spraying and removal of sources such as rotten fish were employed. Products to repel or exterminate flies on the market might provide a useful clue as to measures against flies. Table A shows examples.

Table A

	effect	notes
smell	repellent	Herbs
	attraction	Leek flowers
sound wave	repellent	16*KHz*
electricity	extermination	High voltage
light	attraction	Utilize phototaxis of flies

It should be clarified, through experiments and deeper investigation, which substances are suitable for the target goal and which substances can be used most effectively.

Discussion & Results

(1) Method for repelling

Repelling flies by smell was tried because it would be easier to employ and more feasible than other countermeasures. For example, ultrasonic waves and electricity cannot be used everywhere in the event of a disaster. Therefore, they are not suitable for these purposes. In fact, when sending a high-frequency sound, people could hear the sound and felt uncomfortable. Moreover, a pleasant smell is superior in that it serves for treatment of diseases and trauma, prevention of diseases, improved physical and mental health, relaxation and relieving stress as typified by aromatherapy. However, it should be taken into account that some people might feel uncomfortable depending on their preference.

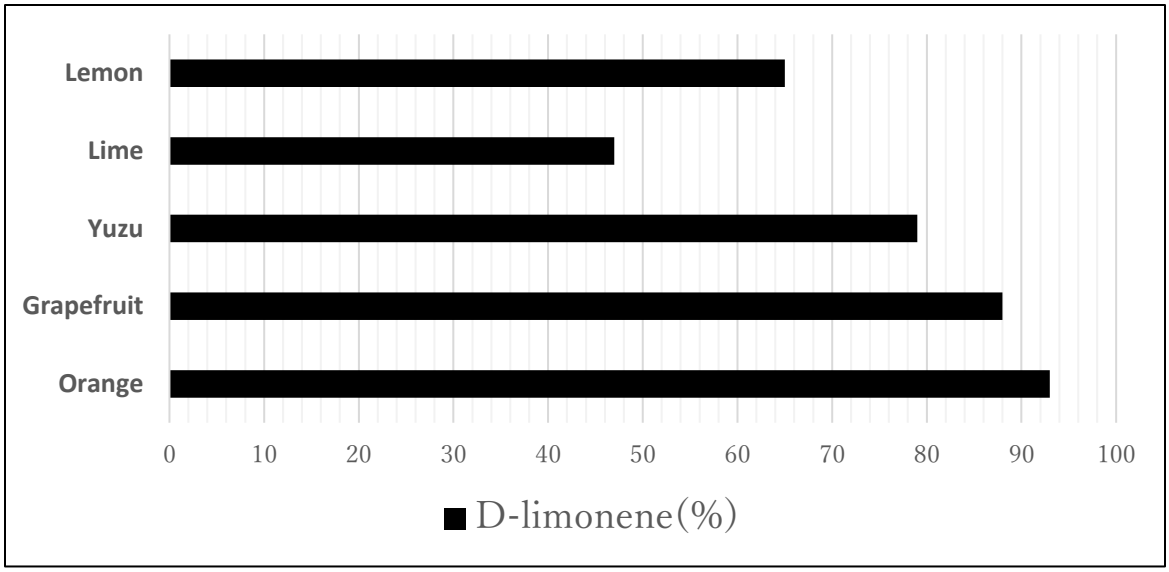
A substance, *D-limonene* was focused on, which is included in citrus plants such as oranges. In the course of our research, it was revealed that many plants including Thyme, Chamomile, Orange, Tansy, and Lime have a repellent effect. All these plants include *D-limonene*, which is potent against flies. It is reported that D-limonene caused flies of Formia to lose their appetite. It seems right to presume, from the fact that familiar plants such as oranges and grapefruit contain a lot of *D-limonene*, that taking measures against flies at low cost would be possible. However, because it is in the state of essential oil that the effect is certified, it must be verified whether the effect is also recognized from the fruit or fruit juices.

Here, the definition of essential oil is confirmed. Regarding aromatic oil, according to *AEAJ*, the public-interest corporation approved by *the Japanese Cabinet*, the definition of essential oil is as follows:

Essential oil is a natural material extracted from flowers, leaves, pericarps, fruits, heartwood, roots, seeds, bark and resin of plants, and is a volatile fragrance substance which contains high concentration of effective substances. Each plant has a peculiar scent. It is the basis of aromatherapy. (Aroma Environment Association of Japan. Seiyu towa, (What is Essential Oil?))

Grapefruit and Orange aroma oil have a content of *D-limonene* as high as 90%. An indication of the content of *D-limonene* (hereinafter, referred to as limonene) in essential oil of each plant is as

follows:



Although the amount of limonene contained in orange juice is unclear, according to *Research on the functional ingredients of Tachibana*, the amount of essential oil extracted from a ripe fruit (whole) and its leaves is about 0.1%, and from a ripe pericarp is about 0.3%. Therefore, it can be presumed that the content of limonene in orange juice is much less than in orange aroma oil.

(2) Examination and experiment on limonene

This section explains the properties of limonene. The following information is quoted from the *Concise International Chemical Assessment Document* by the National Institute of Health Sciences. Limonene is included in some kinds of trees and shrubs and is mainly released into the atmosphere by biological activities and human activities. The details appear in Table B below.

B

Melting point（℃）	-74.35
Boiling point（℃）	175.5～176.0
Specific gravity （at 20℃）（g/cm³）	0.8411
Solubility in water （at 20℃）（mg/L）	13.8
Alcohol	soluble [*1]
Plastic	Limonene dissolves and deteriorates polystyrene, and also dissolves AS (styrene, acrylonitrile, copolymer) obtained by polymerizing styrene and

	acrylonitrile.
Inflammability	positive　　flash point：48℃[*2]
Spontaneous combustibility	positive　　ignition point：237℃[*3]
Color	colorless
Toxicity	quite low（little skin irritation[*4]）
Volatility	positive
Storage	avoid direct sunlight, store in a cool and well-ventilated place tightly seal the container (glass) in order to prevent oxidation of limonene
On the ground	When it is on the ground, it is expected that it doesn't move into the soil on the basis of physical/chemical properties.
In a natural aquatic environment	In an aquatic environment, it is absorbed to bottom sediment and organic matter, and it is expected to volatilize rapidly on the basis of physical/chemical properties.
Impact on the environment	Terpenes such as limonene are responsible for the formation of urban ozone (*Gäb and others,1985; Sekiya and others,1988*). Limonene and other terpenes are largely released to the atmosphere in large quantities, and it is possible that they cause decreased levels of ozone at lower nitrogen oxide concentrations. They also cause an increased level of ozone at higher nitrogen oxide concentrations (*Altshuller,1983; Fehsenfeld and others,1992*). Ozonolysis by limonene also leads to the formation of hydrogen peroxide and organic peroxides, have various toxic effects on plant cells and might be the cause of deforestation observed in the past several decades (*Peters and others,1994*).
Impact on human health	Case reports or epidemiological studies on the impact on human health are not confirmed.
Main method for application	It serves as a substitute for chlorinated hydrocarbon chlorofluorocarbons and other solvents. It is also used for degreasing metal before industrial coating (30% limonene), washing in electronics industry (50~100% limonene) and in the printing industry (30~100% limonene) as well as in paint as a solvent. In addition, it is used for food flavors, fragrant food additives, and household cleaning agents. D-limonene is used for gallstone-dissolving agents (*Igimi and others,1976,1991*).

*1 cited from *Britannica International Encyclopædia*

*2 cited from *Takemoto Yohki Co., Ltd. -properties of plastic and its chemical resistance*
*3 cited from *Hazardous Substances Data Bank. National Library of Medicine*
*4 when this material is oxidized, repeated or long contact may cause skin sensitization, inflammation, pruritus, soreness, and rash were observed in a subject whose skin was exposed to d-limonene (98%) for 20 hours.
Limonene has mirror image isomers, D bodies and L bodies, and the former has a repellent effect.
Information on the yield and cost of limonene was considered with reference to previous research and products on the market. According to *Orange Oil Extraction and Its Utilization Method*, the yield varies depending on the extraction method, 0.0129% in the steam distillation, and 1.63% in solvent extraction. Although it isn't clear how commercial limonene is extracted, the concentration of it is from 90 to 98%.
An experiment to extract limonene was undertaken. Its purpose was to extract limonene and to clarify the yield of limonene. Steam distillation was decided as the method for the experiment. Limonene in the extract was detected based on decolorization of potassium permanganate by a limonene double bond. However, its concentration was unclear. Therefore, the results were judged by observing whether foaming polystyrene would be melted by utilizing the property of limonene that melts it. A drop of aroma oil with limonene content over 90% melted a hole about 1cm deep. On the other hand, no change was observed when the liquid obtained by distillation was used. This result shows the content of limonene was low. Moreover, the lemon odor, which is particular to limonene and is necessary for repelling flies, was not noticeable in the extract. Therefore, increasing the concentration of limonene remained as the next task.

(3) Consideration of specific measures

There is an element to consider concerning the properties of limonene. Among the properties shown in (2), what must be noted in terms of its usability and safety is that it can cause irritation of skin as well as dissolving and deteriorating some plastics. In addition, it has been pointed out that D-limonene and its oxides are harmful to the liver and kidneys, are carcinogenic in rats, and are toxic to fish. These facts have to be considered. According to *Recyclability of marine debris Research Report　SONY method　Polystyrene High Quality Recycle System　Accompanying Sheet 2*, it was revealed by the public agency that the limonene solution with 20%, in which Styrofoam is dissolved, is ignited as a result of throwing a lit cigarette. A public institution revealed that limonene solution (20% dissolved styrene foam) doesn't ignite even if a lighted cigarette is thrown into it. Therefore, inflammability wasn't taken into account this time. Because of the above concerns, it is unfavorable to use limonene in high concentration expecting a repelling effect of a wide range.

Our goal is to make a form for practical use. To achieve this requires revealing interaction and changes in its effects when it is combined with materials. Therefore, the conditions required for the material to be combined need to be clarified. Our goal is to repel flies at evacuation centers with the

smell of limonene. Thus, the criteria for evaluating the materials to be combined are duration, processing flexibility, manageability, cost, and safety. Moreover, it is expected to be used in the following three places; entrances, toilets, and trash boxes, around which flies typically gather.

An interview by email yielded useful information to deepen the study. An interview with the *Japanese Society of Aromatherapy,* which has been carrying out volunteer support activities since the 2016 Kumamoto Earthquake, was held via email. The interview was about the problems and difficulties in terms of obtaining and distribution goods to disaster-stricken areas in helping the victims with aromatherapy goods. In addition, it covered the data and papers which indicate limonene's repelling and insecticidal effects against flies.

The answer to our question about problems with obtaining and distributing materials was as follows:

1. There were few problems because the activity started two months after the disaster, when the transportation network was improved.
2. The association donated aromatherapy goods such as essential oils and the necessary supplies for support as well as offering subsidies for the activity.

Furthermore, they told us about the concrete situation at the time of support.

3. "Outdoor Body Sprays," which volunteers from JSA distributed and which have a deodorizing and sterilizing effect, were popular among the users. However, some said that their smell was too strong. Depending on personal preference, the strength of odor should be considered.
4. Even two months after the accident, the information network in the devastated area was tangled. Therefore, there were times when things that are not in demand arrived and they had trouble dealing with them.

To improve such a problem, the situation, location, and effect should be deeply considered to make a concrete proposal.

(4) Concrete proposal

Following the last section's findings, some forms are referred to for practical use in this section.

Around the toilet and the trash box, there are sulfur compounds around which flies breed. The authors examined the shapes of products made to fight against uncomfortable odors in toilets and the trash boxes on the markets. The placed type, hanging type, seal-shaped type, and spray type seemed to be popular. However, the non-fixed type and the hanging type are unsuitable when taking evacuation centers into account. Although there are many kinds of natural disasters, using the aftershock as an example, the non-fixed type is likely to drop and be broken. In addition, there is a possibility that its place may be shifted and it might not work sufficiently. Therefore, the seal-shaped type is focused on in our research. It is made to attach to the lid of the trash box.

Picture1 shows our trial product. This is a simple one with a gauze on the plastic base for soaking

it with limonene and a cover is attached on the plate in order to prevent users from directly contacting the gauze. The outer side of the base plate is an adhesive face so that it is used by sticking it to a trash box. In addition, it can be hung by using string through the cover metal. In terms of its cost, all the materials are available in a hundred-yen store and there is no piece that is difficult to obtain. Furthermore, it can be used long-term by changing the gauze when its repellent effect declines. Its simplicity has to be improved in the future. In terms of its safety, as described above, the gauze portion is covered so as not to come in direct contact with the outside, due to the properties of limonene, plastic deterioration and skin irritation. Since the plastics which limonene dissolves are polystyrene and acrylonitrile, it is expected that limonene is not likely to dissolve the plastic base plate made of polyvinyl chloride. Disposal of gauze as a combustible does not cause it to flow directly into the sewage and its impact on aquatic organisms will be extremely low. It is interpreted from the above that there are few problems regarding cost and safety.

Picture 1

In order to clarify the effectiveness level, the duration of use, and the manageability, the five kinds of experiments below were conducted.

A Nothing except a paper plate

B A paper plate and rotten garbage

C A paper plate, rotten garbage and essential oil of Orange Sweet 0.2ml

D A paper plate, rotten garbage and essential oil of Orange Sweet 0.4ml

E A paper plate, rotten garbage and essential oil of Orange Sweet 0.2ml

The purpose of experiment A was to indicate that the plate has no repellent effect on flies and the purpose of experiment E was to clarify that only the essential oil of Orange Sweet has a repellent effect in all the experiments. The diameter of the paper plate is 17cm and rotten garbage, an attractant was put on it. The rotten garbage consists of rice, banana, cut fish, and pork, and the amount of each was

25g. In order to make it rotten, the garbage had been left outside for four days before the experiments were conducted. The size of a mosquito net, an experimental field, was approximately 3.2 square meter. In each experiment, 20 flies were put into the mosquito net. Flies used in the experiment were obtained by raising red larvae, which are sold as fishing bait. Red larvae are artificially cultured larvae of *Lucilia caesar*. This species of flies has a characteristic of narrow-placed mating, and are very troublesome after they breed in a narrow trash box. Therefore, it is useful to repel them at evacuation centers. Each experiment was continued for one hour. The properties and components of essential oil of Orange Sweet used in the experiments are shown in the table C below.

C

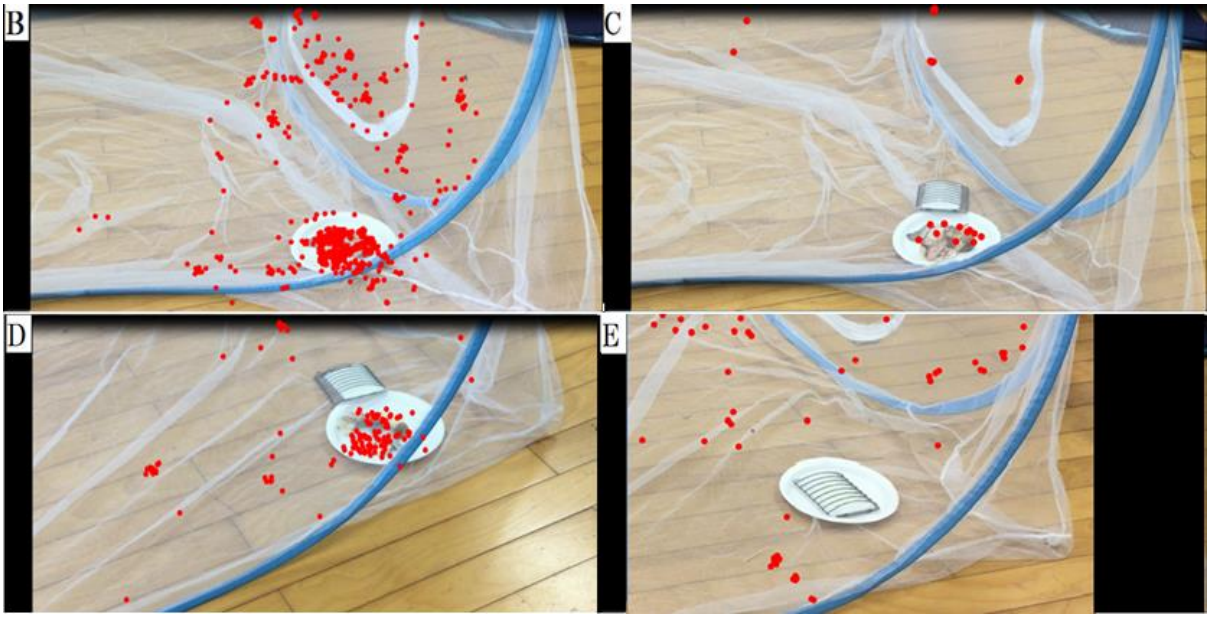
Orange Sweet	
Physical property	
Index of refraction (20℃)	1.473
Specific gravity (20℃)	0.845
Optical rotation (20℃)	97.2
Flashpoint	47℃
Components	
Terpene hydrocarbon	
Limonene	95.75%
Myrcene	1.82%
α-Pinene	0.49%
Sabinene	0.27%
Valencene	0.02%
Terpene alcohol	
Linalool	0.39%
Aldehyde	
Octanal	0.20%
Decanal	0.12%

(cited from *Tree of Life-essential oil of orange sweet*)

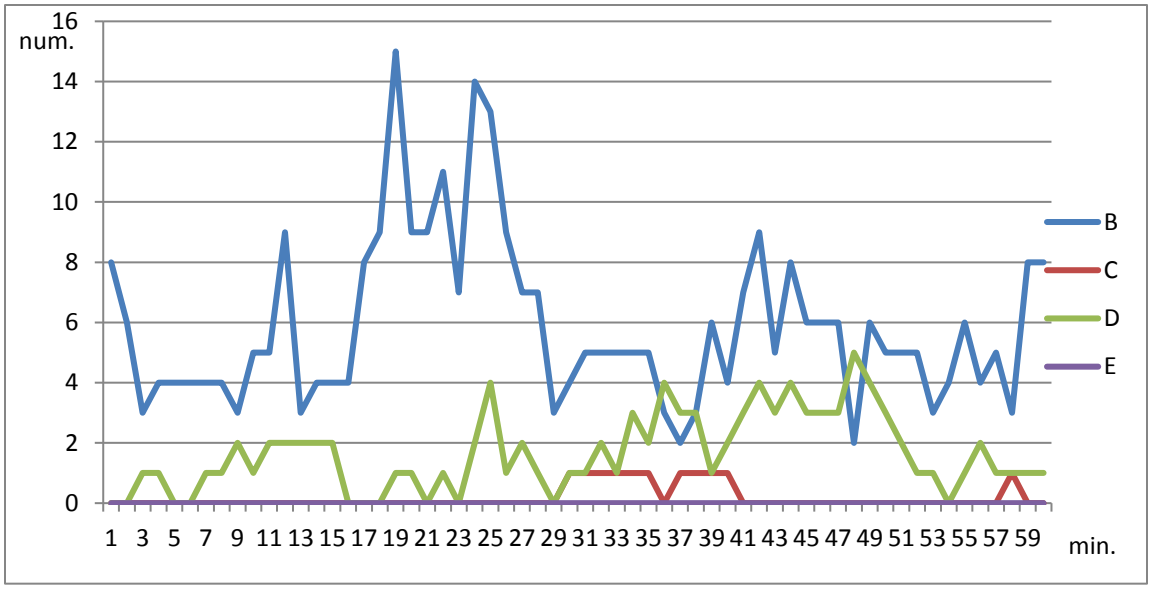
A repellent effect is defined by the *repelling rate*. The *repelling rate* is derived by calculating, {(the number of flies gathering only around the attractant) – (the number of flies gathering around both the attractant and the repellent)} / (the number of flies gathering around both the attractant and the

repellent) * 100 (%).

The results were analyzed based on the record of a fixed camera. Each one-hour record was divided into photos by one minute. The spots where flies landed on was marked with dots. By performing superimposing compositions of the photos (from B to E below), the density of flies was measured. In addition, the repelling rate was calculated by taking the average number of flies in each photo. In experiment A, flies were homogeneously broadened and no change was observed.



	B	C	D	E
Total number	353	11	99	0
Average	5.9	0.2	1.7	0
Repelling rate		97%	71%	



The dots in the above picture indicate where the flies have stayed, and the total and average numbers in the table is the number of times flies landed on the plate. Furthermore, the line charts show the number of flies which gathered.

The results provide sufficient evidence to say that our trial product has enough of a repellent effect. In addition, since the repelling rate was calculated based on the average of one hour, it can be presumed that it continues for at least one hour.

Conclusion

As described above, it was clarified that limonene has a repellent effect on flies. Although not all flies are repelled, it can be expected that limonene can reduce risk from flies and can contribute to the improvement of hygienic environment. Our trial product is just one example. Various applications promise a certain level of effect.

The discussion of the way to obtain and supply is a necessity. It is mentioned briefly here. Aroma oil of plants such as orange and grapefruit is not necessarily inexpensive and it might be difficult to prepare much aroma oil. Therefore, it is probably one of the most effective means to request the cooperation of other institutions. As mentioned in the last section, the *Japanese Society of Aromatherapy*, engage in supportive activities for the victims after a major earthquake or a heavy rainfall disaster by providing aromatherapy products for them. The activities bring comfort and relief to many of the victims. It is expected that they continue to promote reconstruction in disaster-stricken towns for many years to come. Therefore, it would be possible to take our measures against flies by utilizing aromatherapy products. If it is suggested, when the products reach the affected as relief goods, that they can be useful for repelling flies, the goods will be broadly applicable and will be helpful to the promotion of hygiene at evacuation centers. It is hoped that cooperation with institutions dealing with

aromatherapy products such as JSA is achieved.

Research on repellent effects is worthwhile. As stated above, there are few reports on repelling flies. In conclusion, we should raise awareness and support the development of knowledge in this area. We believe that our research can contribute to the progress of this field, repelling flies. It is hoped that our continued research will contribute to the promotion of hygiene at evacuation centers.

This research project would not have been possible without the contribution and advice of many people and institutions. Their advice and knowledge of the research topic are greatly appreciated and gratefully acknowledged.

We would like to pay special thanks, warmth, and appreciation to the persons below who made our research successful and assisted us at every point toward our goal:

Kasai Shinji and Komagata Osamu, members of National Institute of Infectious Diseases, for their answers to the questions about flies and advice about our experiments.

Ozaki Mamiko, a professor of the Graduate School of Science / Faculty of Science at Kobe University, for giving interesting answers about flies and limonene, and advice about our research.

Usui Masaru, an associate professor at Rakuno Gakuen University, for providing accurate information about flies and infectious diseases.

Kazama Makoto, who belongs to Nekken Bio-Resource Center at Nagasaki University, for polite replies to our questions about flies.

The members of the Japanese Society of Aromatherapy for sharing their experiences of their assistance activities and efforts at disaster-stricken towns as well as information about aromatherapy which helped us to simulate conditions after a natural disaster.

Yamanaka Yumiko, a member of Kyushu Christ Disaster Relief Center, for a detailed description about hygiene at evacuation centers after the Great Hanshin-Awaji Earthquake.

Nakano Naoko, Onizuka Koji, Inoue Seiko, and Ueno Yusuke, our teachers, for their cooperation for our experiments.

Thank you all for your support and guidance.

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