

Granular Composition for Release of Volatile Oil

FIELD OF THE DISCLOSURE

The present disclosure relates to a granular composition for the release of a volatile oil in a sustained-release manner, and further relates to pest control product.

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BACKGROUND OF THE DISCLOSURE

One of the more significant causes of waste pollution, such as, air pollution, water and soil contamination, is poor waste management, which is the improper disposal of wastes, such as, used plastic bags and bottles.

10 Disposal of waste tyre rubber has long been recognized as a major environmental issue in the recent years. An estimated 1000 million tyres reach the end of their useful lives every year and 5000 million more are expected to be discarded in a regular basis by the year 2030. At present, only a small part is recycled and millions of tyres are just stockpiled, landfilled or buried (F. Azevedo, et al., Construction and Building Materials, Vol. 34, Sept 2012, Pages 186-191).

15 Discarded tires are notorious for providing shelter to rodents, creating ideal breeding conditions. Their hollow structure offers protection from predators, allowing rodents to thrive and reproduce in urban and suburban environments. Additionally, tires contribute to the spread of zoonotic diseases, as rodents can transmit various diseases such as hantavirus and salmonella to humans through their droppings and urine. Moreover, the stagnant water that accumulates
20 inside tires serves as a breeding ground for mosquitoes, which are vectors for diseases such as malaria, dengue, and West Nile virus (Pest Control Technology, 'Strategies for Urban Rodent Control' (PCT Online, 1999)). Governments have enacted regulations to minimize the environmental impact of waste tires. Many recycling programs focus on reducing the number of tires in landfills or repurposing them for energy recovery and construction materials. However,
25 these solutions do not address the role that discarded tires play in fostering rodent populations. Whilst recycled crumb rubbers are now commonly used for construction, there is still a strong and unmet demand for novel ways for rubber waste management. A new way of repurposing waste, rubber is therefore highly desired.

In the field of pest control, commonly used pesticides, insecticides, chemical repellents and
30 rodenticides are known to be associated with a number of disadvantages. For instance, they are often "single-use" items and include toxic compounds that pose significant safety risk to users

and other non-target species, such as pets and wildlife. Additionally, the toxic ingredients in these synthetic products can contaminate soil and water, causing environmental concerns. Over time, the target pest (e.g. rodent) populations would also likely develop resistance to certain chemical agents, rendering them less effective.

- 5 Alternative rodent control method includes habitat modification programs, such as removing food sources and shelter, have been effective in reducing rodent populations in urban environments, however, they are often costly and difficult to implement. Rodent traps, such as glue traps, with baits are traditionally used in capturing rodents. However, these capture methods are considered inhumane and required routine maintenance; and the effectiveness of the use of baits is often compromised by the complex environments created by human activities.

Therefore, there exists substantial interest in the development of alternative pest control products that are non-toxic, environmentally friendly, and compatible with human and animal use.

- 15 Although the use of natural oils as pest repellent against mosquitoes, rodents and cockroaches are known, most of the available products are disposable single-use products; and the effectiveness thereof are often short-lived, leading to the need of frequent and costly replacement.

There remains a need for a sustainable solution to rubber waste management and to repurpose wasted, used, or old rubber into a value-adding product.

- 20 There also remains a need for a safer, more effective and environmentally-friendly alternative to traditional pest control methods.

It is an object of the present disclosure to address or at least partially ameliorate some of the above problems of the current approaches.

25 SUMMARY OF THE DISCLOSURE

Features and advantages of the disclosure will be set forth in the description which follows, and in part will be apparent from the description, or can be learned by practice of the herein disclosed principles. The features and advantages of the disclosure can be realized and obtained by means of the instruments and combinations as claimed by the appended claims.

In accordance with a first aspect of the present disclosure, there is provided a granular composition for the release of one or more volatile oils, comprising rubber granules carrying a hydrophobic component comprising at least one volatile oils. In an embodiment, the hydrophobic component may be provided on the rubber granules, or impregnated within the rubber granules. Advantageously, the release of one or more volatile oils may be sustained over a duration of 30-60 days.

In one embodiment, the rubber granules may be crumb rubber derived from a feedstock selected from rubber tyres, gaskets, belts, hoses; and are sized between 1-10mm in diameter.

In one embodiment, the volatile oils in the hydrophobic component may be essential oils or synthetic oils. Advantageously, the volatile oils may be essential oils selected from the group consisting of citronella oil, chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary oil, lavender oil, tea tree oil, neem oil, oregano oil, clove oil, cinnamon oil, thyme oil, garlic oil, wintergreen oil, lemongrass oil, lavender oil, lime oil, geranium oil, anise oil, angelica oil, basil oil, bay oil, bergamot oil, camphor oil, cananga oil, cardamom oil, caraway oil, cedar oil, cedarwood oil, Chamaecyparis obtusa oil, chamomile oil, cinnamon oil, citronella oil, clove oil, copaiba balsam oil, cumin oil, clove oil, coriander oil, dill oil, eucalyptus oil, fennel oil, garlic oil, geranium oil, grapefruit oil, ginger oil, guaiac oil, hiba oil, iris oil, Japanese mint oil, jasmine oil, lavender oil, lemon oil, lemongrass oil, linaloe oil, Lindera oil, mandarin oil, mint oil, neroli oil, onion oil, orange oil, oregano oil, patchouli oil, parsley oil, pepper oil, peppermint oil, perilla oil, Peru balsam oil, petitgrain oil, pine oil, pine needle oil, rose oil, rosemary oil, sandalwood oil, spearmint oil, star anis oil, tangerine oil, tea seed oil, tea tree oil, thyme oil, tolu balsam oil, tuberose oil, turmeric oil, vetivert oil, western mint oil, wintergreen oil and any combination thereof.

In one embodiment, the hydrophobic component comprises one or more essential oils selected from the group consisting of citronella oil, chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary Oil, lavender oil, tea tree oil.

Optionally, the hydrophobic component may further comprise an agent selected from the group consisting of pheromones, odor-neutralizing agent, odor-masking agent, additive, stabilising agent, antimicrobial agent, UV-blocking agent, moisture control agent.

In one embodiment, the granular composition described herein may further comprise a nanoparticle component, which may comprise one or more metal oxides. For example, the nanoparticle component may comprise, in weight percentages:

5-11% titanium dioxide (TiO₂),

2-7% zinc oxide (ZnO),

10-15% fumed silica,

1-2% magnesium oxide (MgO),

5 1-2% calcium carbonate (CaCO₃),

0.5-1% aluminum oxide (Al₂O₃),

and 0.5-1% silicon dioxide (SiO₂).

Optionally, the nanoparticle component may further comprise barium sulfate (BaSO₄), talc, or zeolites; and/ or a stabilizer, an antioxidant or a catalyst.

10 In one embodiment, the granular compositions described herein are provided for use in a method of pest control, and the volatile oil in the composition may be a pest repellent or a pest attractant.

In accordance with a second aspect of the present disclosure, there is provided an article comprising a container housing the granular composition as described herein. In one
15 embodiment, the container may be made from aluminium comprising a sealable aluminium lid with a plurality of apertures defined therein for transmission of vaporised volatile oils therethrough. Optionally, the aluminium lid is overlaid with a cellophane film or a cotton muslin fabric.

In another embodiment, the container may be a plastic bottle comprising a sealable plastic lid
20 with a plurality of apertures defined therein for transmission of vaporised volatile oils therethrough.

In accordance with a third aspect of the present disclosure, there is provided a method of controlling pests by exposing the pests to the granular composition or the article as described herein. The pests that can be controlled by the method may be rodents, cockroaches,
25 mosquitoes, bed bugs, fleas, ants, silverfish, firebrats, aphids, termites, weevils, beetles, mites, millipedes, centipedes, sowbugs, crickets, ants, flies, or spiders.

In one embodiment, the method of the present disclosure can be used to control pests, including cockroaches, mosquitoes, bed bugs, or fleas. In a preferred embodiment, the method of the present disclosure can be used to control rodents.

Optionally, the method may further comprise the step of refilling the article with one or more volatile oils.

In accordance with a fourth aspect of the present disclosure, there is provided a method of preparing a composition, comprising: mixing rubber granules of 1-10mm with a hydrophobic component comprising one or more volatile oils; and optionally, adding and mixing a nanoparticle component.

BRIEF DESCRIPTION OF THE FIGURES

In order to describe the manner in which the above-recited and other advantages and features of the disclosure can be obtained, a more particular description of the principles briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended Figures. Understanding that these Figures depict only exemplary embodiments of the disclosure and are not therefore to be considered to be limiting of its scope, the principles herein are described and explained with additional specificity and detail through the use of the accompanying Figures.

Preferred embodiments of the present disclosure will be explained in further detail below by way of examples and with reference to the accompanying Figures, in which:-

FIG 1 depicts the preparation of the granular composition according to an embodiment of the present disclosure.

FIG. 2 is a photograph of the granular composition according to an embodiment of the present disclosure.

FIG 3 depicts a simplified structure of the granular composition according to an embodiment of the present disclosure.

FIG. 4 depicts an exemplary aluminium can containing the granular composition of the present disclosure.

FIG. 5 depicts an exemplary plastic bottle containing the granular composition of the present disclosure.

FIG. 6A is a graph showing the effects of the granular composition of the present disclosure.

FIG. 6B is a photograph of a rodent at the testing site captured by infra-red camera.

FIG. 6C depicts the computer logs created from rodent activity captured by IoT device triggered by motion sensors.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 The present disclosure relates to the upcycling of unwanted rubber by providing a granular composition comprising rubber granules and a hydrophobic component, for use in releasing one or more desired agent provided in the hydrophobic component. The rubber granules act as a carrier or platform for the hydrophobic component, comprising one or more desired agents, which may be a blend of volatile oils, e.g., essential oils. Optionally, the granular composition
10 may be provided with a nanoparticle component for enhancing the physical characteristics of the granules. r.

It is envisaged that the porous structure of the rubber granules act as a core substrate, which allows the active ingredient to be absorbed, embedded, or impregnated onto the granules, such that the active ingredient is gradually released therefrom during use, providing a prolonged,
15 extended-release profile. Amongst various applications, the granular composition of the present disclosure is found to be particularly suited for releasing pest repellent or attractants over an extended period of time, as further described in the Examples provided herein. As such, the present disclosure further addresses the need for pest control products that are non-toxic, environmentally friendly, and effective over an extended period of time, without the need of
20 frequent replacement, offering a more sustainable and versatile solution to address pest issues as compared to traditional methods.

Various embodiments of the disclosure are discussed in detail below. While specific implementations are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and
25 configurations may be used without departing from the spirit and scope of the disclosure.

Definitions

In order for the present invention to be more readily understood, certain terms and phrases are defined below and throughout the specification. Unless defined otherwise, all technical and
30 scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

Unless specifically stated or obvious from context, as used herein, the term "about" is understood as within a range of normal tolerance in the art, for example within 2 standard deviations of the mean. "About" can be understood as within 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.1%, 0.05%, or 0.01 % of the stated value. Unless otherwise clear from context, all numerical values provided herein are modified by the term "about."

The transitional term "comprising," which is synonymous with "including," "containing," or "characterized by," is inclusive or open-ended and does not exclude additional, unrecited elements or method steps. By contrast, the transitional phrase "consisting of" excludes any element or step not specified in the claim. The transitional phrase "consisting essentially of" limits the scope of a claim to the specified materials or steps "and those that do not materially affect the basic and novel characteristic(s)" of the claimed invention.

Unless specifically stated or obvious from context, as used herein, the term "or" is understood to be inclusive. Unless specifically stated or obvious from context, as used herein, the terms "a", "an", and "the" are understood to be singular or plural.

As used herein, the phrase "at least one," in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified.

As used herein, the term "pest" refers to organisms that negatively affect a host— such as a plant or an animal such as a mammal— by colonizing, damaging, attacking, competing with them for nutrients, or infecting them. This includes vertebrate and invertebrate pests, arthropods including insects and arachnids, including agricultural pests.

As used herein, the terms "control" or "controlling" are meant to include, but are not limited to, any killing, growth regulating, or pestistatic (inhibiting or otherwise interfering with the normal life cycle of the pest) activities of a composition against a given pest.

It should also be understood that, unless clearly indicated to the contrary, in any methods claimed herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited to the order in which the steps or acts of the method are recited.

Other features and advantages of the invention will be apparent from the following description of the preferred embodiments thereof, and from the claims. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. All other published references, documents, manuscripts and scientific literature cited herein are incorporated herein by reference. In the case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

One aspect of the present disclosure relates to a granular composition comprising rubber granules and a hydrophobic component, for use in releasing one or more desired agent provided in the hydrophobic component. The rubber granules provide structural support and act as a carrier or mechanical platform for releasing the hydrophobic component into the surrounding ambient in a slow and gradual manner for an extended, continuous period of time.

In one embodiment, the granular composition is used for releasing of one or more volatile oils, and the composition is provided with the rubber granules carrying a hydrophobic component comprising at least one volatile oils. The hydrophobic component may be infused, embedded or impregnated within the rubber granules, such that the volatile oils can be gradually released from the granules in a controlled, sustained release manner, over an extended period of over 30, preferably over 60 days, and most preferably over 90 days.

Advantageously, the rubber granules can be derived from wasted, recycled, or old rubber. For example, the granules may be crumb rubber derived from a feedstock selected from rubber tyres, gaskets, belts, hoses, pipes, shoes, and other sporting goods, household supplies and automotive products. Optionally, the crumb rubber is obtained by ambient mechanical grinding or cryogenic grinding. In an embodiment, the rubber granules have the dimensions of 1-10mm, and typically accounts for 65-95%, more preferably 80-90%, most preferably 90%, of the granular composition by weight.

It is envisaged that the unique porous structure of rubber (e.g., discard tyres) acts as a core substrate, providing a passive, controlled release mechanism. This structure allows the active ingredient to be embedded, or impregnated onto the granules, such that the active ingredient can be released gradual diffusion over an extended period, leveraging the tire's natural porosity to achieve long-lasting efficacy.

This newly found application for crumb rubber upcycles a non-biodegradable waste product, diverting it from landfills and contributing to the circular economy. Tires are an abundant, low-cost material that, when repurposed, reduces the overall carbon footprint of the manufacturing process. Rubber tyres, which are often made of elastomeric materials, also offer inherent durability and weather resistance, making them suitable for outdoor uses.

In an embodiment, the active agent in the hydrophobic component of the present disclosure is one or more volatile oils, which may be vaporized and delivered to the immediate environment of the granular composition, where an extended release of the volatile oil(s) is desired. The volatile oil may be an essential oil obtained from natural sources, such as plant extracts, or a synthetic oil, also known as a fragrance oil.

Essential oils are hydrophobic and widely used in pharmaceutical, cosmetic, agriculture and food industries due to their bactericidal, virucidal, fungicidal, antiparasitical and insecticidal properties; and a number of essential oils possess characteristic and intense odor and taste.

Non-limiting examples of essential oils that can be used in the present disclosure include: citronella oil, chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary oil, lavender oil, tea tree oil, neem oil, oregano oil, clove oil, cinnamon oil, thyme oil, garlic oil, wintergreen oil, lemongrass oil, lavender oil, lime oil, geranium oil, anise oil, angelica oil, basil oil, bay oil, bergamot oil, camphor oil, cananga oil, cardamom oil, caraway oil, cedar oil, cedarwood oil, Chamaecyparis obtusa oil, chamomile oil, cinnamon oil, citronella oil, clove oil, copaiba balsam oil, cumin oil, clove oil, coriander oil, dill oil, eucalyptus oil, fennel oil, garlic oil, geranium oil, grapefruit oil, ginger oil, guaiac oil, hiba oil, iris oil, Japanese mint oil, jasmine oil, lavender oil, lemon oil, lemongrass oil, linaloe oil, Lindera oil, mandarin oil, mint oil, neroli oil, onion oil, orange oil, oregano oil, patchouli oil, parsley oil, pepper oil, peppermint oil, perilla oil, Peru balsam oil, petitgrain oil, pine oil, pine needle oil, rose oil, rosemary oil, sandalwood oil, spearmint oil, star anis oil, tangerine oil, tea seed oil, tea tree oil, thyme oil, tolu balsam oil, tuberose oil, turmeric oil, vetivert oil, western mint oil, wintergreen oil and any combination thereof.

In an embodiment, the essential oils selected from the group consisting of citronella oil, chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary oil, lavender oil, tea tree oil.

In one exemplary embodiment, the hydrophobic component comprises a mixture of citronella oil, chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary oil, lavender oil, tea tree oil.

In one exemplary embodiment, the hydrophobic component comprises only citronella oil. In one exemplary embodiment, the hydrophobic component comprises a mixture of lemongrass oil and citronella oil. In one exemplary embodiment, the hydrophobic component comprises a mixture of citronella oil and peppermint oil. In yet another exemplary embodiment, the hydrophobic component comprises a mixture of citronella oil and peppermint oil. The oils may present in weight percentages as shown below:

Exemplary Formulations	Ingredients
1	100%. Citronella Oil
2	30% Lemongrass Oil
3	60% Citronella Oil; 40% Peppermint Oil
4	40% Citronella Oil; 60% Cedarwood Oil

Optionally, the hydrophobic component further comprises an agent selected from the group consisting of pheromones (e.g., testosterone, androsterone and progesterone), odor-neutralizing agent, odor-masking agent, additive, stabilising agent, antimicrobial agent, UV-blocking agent, moisture control agent.

In one embodiment, the hydrophobic component may be provided with weather resistant coatings, time release encapsulation, or a biodegradable film layer. Additional optional ingredients exempt under the EPA regulation can be added to the hydrophobic component, including Sodium Bicarbonate, Citric Acid, Vanillin, Soybean Oil, Mineral Oil (USP or NF grades), Vitamin E (Alpha-Tocopherol), Ascorbic Acid (Vitamin C). Additional aroma compounds extracted from urine of animals (e.g., cat, fox, snake) can be added as required.

Generally, the natural oils account for 5-30% w/v. more preferably 10-20%, most preferably 12-18%, of the granular composition. As essential oils are natural oils that are non-toxic and biodegradable, the resulting product is safe to humans and pets, and aligns with current regulatory and environmental standards. It is known that natural oils are generally regarded as safe (GRAS) by regulatory bodies such as the FDA and are widely used in cosmetic and food.

For the application of pest control, essential oils with high concentrations of active compounds, such as menthol, eugenol, or limonene, are particularly preferred due to their proven effectiveness in deterring rodents. The use of natural oils as pest repellent / attractants offers a non-toxic alternative to synthetic chemical pesticide, such as, naphthalene, which poses a

number of risks, including human safety, environmental contamination, and bioaccumulation in ecosystems. Additionally, the selected oils are biodegradable and break down naturally without leaving harmful residues in the soil or water.

5 In one aspect, the granular compositions of the present disclosure formulated with different blends of essential oils are used in combination, either simultaneously or sequentially (e.g., by rotation), to improve efficacy and overall outcome in pest control.

10 It is well known that, over time, the exposure of a pest population to a single repellent can lead to behavioral or genetic adaptations, rendering it less effective against the pest. To address the issue of resistance build-up in the pest populations (e.g., rodent population), the pest can be exposed to a number of granular compositions of the present disclosure, each comprise a different chemical composition, by rotation. By rotating the active compounds (derived from different natural oils) across product cycles, the composition of the present disclosure prevents unwanted pests (e.g., rodents) from developing resistance. This adaptability is particularly important for ensuring long-term efficacy in areas with high pest activity.

15 In one embodiment, the granular composition may be provided with a nanoparticle component for enhancing the physical characteristics of the granules, such as increased weather-resistance, making it suited for outdoor applications. In an embodiment, the resulting composition is a multi-phase structure with multiple layers, that attribute to the gradual release of active ingredients over time. In another embodiment, a homogenous distribution of volatile oil and nanoparticle solution is provided throughout the surface of the rubber granules, ensuring even coverage and consistent performance.

25 The nanoparticle component may comprise nanoparticles engineered to form a protective barrier over the oil-based hydrophobic component, shielding it from degradation by environmental factors such as UV radiation, moisture, and heat. It is envisaged that the nanoparticles form a thin, impermeable barrier over the volatile oils, reducing and/or substantially preventing environmental degradation. This feature further ensures that the active ingredients remain potent for longer periods, particularly in outdoor settings where exposure to sunlight and humidity would normally significantly reduce efficacy of the active ingredients over time.

30 In an embodiment, the nanoparticle component may comprise hydrophobic and/or photostable nanoparticles, such as, titanium dioxide (TiO₂) and zinc oxide (ZnO). The addition of hydrophobic and/or UV stable nanoparticles further enhances the oil's longevity, allowing it to remain functional even in harsh outdoor environments where typical active ingredients (e.g.,

repellents) would degrade. In one aspect, the nanoparticles also aid in ensuring that the oil maintains its intended concentration and viscosity, further extending its duration of effectiveness. The nanoparticle component may comprise a solvent or may be prepared without a solvent.

- 5 In an embodiment, the nanoparticle component comprises titanium dioxide (TiO_2) and zinc oxide (ZnO), and one or more ingredient selected from the group consisting of fumed silica, magnesium oxide (MgO), calcium carbonate (CaCO_3), aluminum oxide (Al_2O_3), and silicon dioxide (SiO_2), barium sulfate (BaSO_4), and talc.

- 10 It is expected that titanium dioxide provides UV protection and is able to shield the volatile oils from photodegradable, whereas zinc oxide acts as a secondary UV protector and enhances the hydrophobic properties of the nanoparticle coating, ensuring that the oils are protected from moisture and humidity. Fumed silica may be added to provide additional structural reinforcement to the nanoparticle coating, ensuring that the coating remains intact even in harsh environmental conditions. Additional oxides can be incorporated to further increase the stability of the nanoparticle coating, providing resistance to heat, chemical degradation, and mechanical wear. These materials are well-documented to be safe for human and animal use.

- 15 In a preferred embodiment, the nanoparticle component comprises (by weight percentage): 5-11% titanium dioxide (TiO_2), 2-7% zinc oxide (ZnO), 10-15% fumed silica, 1-2% magnesium oxide (MgO), 1-2% calcium carbonate (CaCO_3), 0.5-1% aluminum oxide (Al_2O_3), and 0.5-1% silicon dioxide (SiO_2).

Trace amounts of barium sulfate (BaSO_4) and talc, each under 1%, can be incorporated into the nanoparticle component to modify the physical properties and enhance the dispersion stability of the nanoparticles within an oil base.

- 25 Optionally, zeolites can be further incorporated into the mixture, for example, at a concentration of less than 10%. Zeolites are microporous, aluminosilicate minerals that can enhance the functionality of the product by improving the dispersion of nanoparticles, providing additional structural support, and offering moisture-absorbing properties that further protect the essential oils from environmental degradation.

- 30 The nanoparticle component is synthesized by mixing the above constituents to form a stable emulsion, before adding the emulsion to the oil infused rubber granules. Typically, when the nanoparticle component is present, it is present in the weight percentage of 5-20%, more preferably 5-10%, most preferably 5-8%, of the granular composition.

This emulsion is particularly designed to protect essential oils embedded within from environmental degradation, benefiting from the synergistic effects of the incorporated nanoparticles.

5 In addition, the granular composition of the present disclosure may comprise one or more additional ingredients, such as a stabilizer (e.g., Tocopherol) or a catalyst. The additional ingredient may exist in either of the hydrophobic component, the nanoparticle component, or separately on its own.

10 As described herein, the granular composition of the present disclosure can be used in a method of pest control, for instance, in the delivery of a pest repellent or pest attractant to an area where pest control is desired. Pest repellent combats a target pest by discouraging a target pest from landing on a surface or entering an area, whereas pest attractant is generally used to lure a target pest to a trap

15 In one aspect of the present disclosure, there is provided an article comprising a container housing the granular composition as described herein. In one embodiment, the container is an aluminium can comprising a sealable aluminium lid, for example, as shown in Fig. 4. The lid can be provided with a plurality of apertures, preferably in the shape of circle or hexagon) defined therein, allowing the transmission of vaporised volatile oils through the apertures to the surrounding environment where the article is deployed. Advantageously, the aluminium lid is overlay with a membrane or a thin film made of cellophane or a cotton muslin fabric which can prevent spillage of the rubber granules without affecting the transmission of the volatile oil. The lid and the underlying film also function together to prevent external contaminants from compromising the integrity of the active ingredient and facilitates its controlled release over time.

25 In one embodiment, the container housing is a plastic bottle, which may be prepared from recycled plastic, comprising a sealable plastic lid, as shown in Fig. 5. The lid can be provided with a plurality of apertures defined therein, for example, in the shape of elongated slits, allowing the transmission of vaporised volatile oils through the openings to the surrounding environment. Optionally, a fire-resistant coating can be applied to the outside of the aluminium can or plastic container for safety.

30 In yet another embodiment, the container housing is in the form of a pouch, which can be made of breathable textile materials. Optionally, the article may include external anchors for fixable of the article to the required locations, e.g., the ceiling. It would be appreciated that different containers may be used for different applications/environments as appropriate.

The granular composition of the present disclosure is prepared by placing 30-200g of rubber granules (1mm-10mm) into a designated container, adding to the granules a hydrophobic solution comprising the volatile oil, and mixing the rubber with the solution thoroughly, such that the oil is evenly distributed and infused into the rubber granules.

- 5 Optionally, following the oil application, a solution of nanoparticles is added to the treated rubber, for example, by spraying, to provide protection of the volatile oil against adverse weather conditions such as sunlight and humidity, thereby increasing the duration of which the volatile oil is released from the rubber granules. The preparation of an exemplary granular composition is shown in Fig. 1 and 2.
- 10 Alternatively, the hydrophobic component and the nanoparticle component may be premixed to form a suspension solution, prior to application on the rubber granule substrate. The granular composition of the present disclosure may also be used in releasing a desired volatile oil in a wide range of applications where a gradual release of volatile oil is desired, for example, in aromatherapy, perfumery, pest control, and the like. As shown in Fig. 3, it is envisaged that the
- 15 oil molecules are embedded or impregnated onto the polymeric structure of the tyre rubber; optional nanoparticles are provided to further enhance the physical properties of the final product. The porous structure of rubber facilitates the controlled release of the repellent, allowing for prolonged effectiveness over an extended period. This controlled release mechanism ensures optimal distribution of the repellent, maximizing its coverage and longevity.
- 20 In another aspect of the present disclosure, there is provided a method for controlling or combating a population of unwanted pest, which comprises exposing the pest to the granular composition as described herein. The target pest can be selected from the group consistent of rodents, cockroaches, mosquitoes, bed bugs, fleas, ants, silverfish, firebrats, aphids, termites, weevils, beetles, mites, millipedes, centipedes, sowbugs, crickets, ants, flies, spiders, or a
- 25 combination thereof. In one embodiment, the pests are cockroaches, mosquitoes, bed bugs, or fleas. In another embodiment, the pests are rodents.

- 30 The granular composition can provide a sustained-release of a volatile oil over an extended period of 30-180 days, 30-120 days, 30-90 days, or 30-60 days, allowing the composition to be used for controlling pest in an extended period in continuous manner, without the needed of frequent replacement, or maintenance.

After an extended period of use, when most of the volatile oils have released from the rubber granules to the surround, the efficacy of the granular composition would be reduced, rendering it less effective in deterring pest. As compared to traditional products that are designed for single-

use, the disclosed compositions can be used in a repeated manner when the infused volatile oils become depleted, providing added benefits in terms of cost and sustainability.

In one embodiment, the disclosed method may comprise a step of refilling the article with the hydrophobic component comprising one or more volatile oil, alone or in combination with the nanoparticle component. In one embodiment, the end users may add a pre-mix solution of volatile oils and nanoparticles by an applicator or dispenser (e.g., dropper, syringe, sprayer).

For indoor use, the refilling step can be performed as required, usually at an interval of 60-180 days, preferably 60-120 days, and most preferably 60-90 days, for optimal effectiveness. For outdoor use, the refilling step can be performed as required, usually at an interval of 30-90 days, preferably 30-60 days, and most preferably 30-45 days, for optimal effectiveness.

It is expected that the resulting product can be used in a sustainable manner for at least 12 months. When the product is no longer desired, the treated rubber can be subject to pyrolysis to achieve zero-waste.

As described herein, the present disclosure provides a novel use of a wasted product (e.g., crumb rubber) based on the inherent porous structure of rubber, which allows the gradual release of a desired active ingredient embedded therein, providing a prolonged, extended-release profile, suitable for a wide range of applications.

Disposal of waste tyre rubber has long been recognized as a major environmental problem. Based on the <https://pnorental.com/tires-impact/>, 110 kg carbon dioxide is emitted from the incineration of one tire. It can be estimated that, by upcycling 40 grams of waste rubber (used in one unit of product) instead of subjecting the same amount of rubber to incineration, 440g of carbon emission is prevented.

As demonstrated in the Example 2, the compositions of the present disclosure were found to produce negligible Volatile Organic Compounds (VOC) emissions in compliance with EPA guidelines, and were tested to demonstrate a significantly stronger coverage (10X) and increased durability as compared to commercially available products.

When the product is being used for pest control, the composition of the present disclosure is able to simultaneously tackle two critical issues, that is, transforming discarded rubber into a valuable resource while effectively managing pest populations. Due to the use of safe and non-toxic natural oils, the composition of the present disclosure can be widely applied across various commercial and residential properties, including shopping malls, private buildings, public housing, hospitals, and other facilities.

In the field of rodent control, traditionally, chemical rodenticides, particularly anticoagulants like warfarin and brodifacoum, are widely used to control rodent populations. These poisons disrupt blood clotting in rodents, causing internal bleeding. Newer, more potent second-generation anticoagulants (SGARs) have been developed to address rodent resistance to earlier formulas.

- 5 However, these chemicals pose significant risks to non-target wildlife, pets, and even humans through secondary poisoning. Moreover, rodent resistance to rodenticides remains a growing issue, as certain populations have developed genetic mutations that render them less susceptible to these toxins. While chemical rodenticides are lethal and therefore provide immediate population control, there are significant safety and environment concerns relating to
- 10 their uses. As such, the presently disclosed rubber-based formulations address the above long felt but unmet needs in pest control, by providing an alternative pest control product that is non-toxic, environmentally friendly, and compatible with human and animal use.

- The present disclosed granular composition is a long-lasting, reusable, and cost-effective product, engineered for the delivery of a pest repellent/attractant in both indoors and outdoors,
- 15 even in humid environments. By infusing natural oils with rubber granules, and optionally with nanoparticle additives, the efficacy and longevity of the pest repellent/attractant is greatly enhanced, ensuring robust protection against pests.

- The product balances pest control effectiveness with environmental sustainability, simultaneously addresses a number of issues concerning safety, environmental risks and resistance build up in pest population, eliminating the health risks and environmental damage associated with chemical repellents/attractants. The ability to easily switch scents by refilling the rubber granules with different essential oils or pheromones adds to the product's versatility and customization for specific needs.
- 20

- As illustrated in the Examples, the disclosed system is designed to be easy to use, refillable, and effective in both indoor and outdoor environments, and is proven to be highly effective in rodent control in studies conducted over one year. The provided recycled rubber pest repellent provides long-lasting fragrance for indoor and outdoor uses also aligns with global efforts to promote circular economy principles and minimize environmental impact. The long-term effect provided by the disclosed product translate to cost savings and efficiency improvements for pest control service providers and their clients.
- 25
- 30

The effects of the present disclosure are illustrated in the Examples described below.

Examples

Example 1: Preparation of Exemplary Rodent Repellent Compositions

Composition A

5 Rubber granules (1mm-10mm) obtained from a commercial source were evenly placed into a container. A mixture of natural oils, including lemongrass oil, citronella oil, and peppermint oil, with a ratio of 10-20% w/v was then applied onto the surface of the rubber.

The composition of Composition A is: rubber granules (tires): 75% by weight and natural oils 15% by weight

10 Composition B

Rubber granules (1mm-10mm) obtained from a commercial source were evenly placed into a container. A mixture of natural oils, including lemongrass oil, citronella oil, and peppermint oil, with a ratio of 10-20% w/v was then applied onto the surface of the rubber.

15 For an outdoor use composition, a nanoparticle mixture was first prepared by mixing a number of oxides and silica forms, as illustrated in Table 1 below. The mixture was thoroughly mixed to obtain a stable emulsion, which was then sprayed onto the treated rubber granules to provide weather resistance property to the composition. This emulsion is particularly designed to protect essential oils embedded within from environmental degradation, benefiting from the synergistic effects of the incorporated nanoparticles.

Component	Weight Percentage
Titanium dioxide (TiO ₂)	35-45%
Zinc oxide (ZnO)	20-30%
Fumed silica	8-12%
Magnesium oxide (MgO)	3-7%
Calcium carbonate (CaCO ₃)	6-10%
Aluminum oxide (Al ₂ O ₃)	5-9%
Silicon dioxide (SiO ₂)	3-7%

20

The composition of Composition B is: rubber granules (tires): 75% by weight, natural oils 15% by weight, nanoparticles 5% by weight.

The treated rubber granules were placed in a container and secured by a lid with a plurality of openings for easy diffusion of the natural oils to its surrounding.

5

Example 2: Performance Tests

The compositions were tested for VOC emissions using gas chromatography-mass spectrometry (GC-MS). The results confirmed that the oils and nanoparticle coatings used in the formulation produce negligible VOC emissions, well below the threshold set by international environmental standards (e.g., EPA guidelines).

10

In order to determine the coverage and effectiveness of the composition of the present disclosure, exemplary compositions were subjected to humidity testing for 60 days, with parameters controlled as follows:

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- Humidity levels: 93% relative humidity, simulating typical environments the product would be placed.
- Temperature: A range between 25°C – 13°C, typical indoor room temperature.
- UV Exposure: Simulated sunlight exposure using UV lamps to mimic natural light conditions

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The results demonstrated that the composition of the present disclosure offers 10X stronger coverage as compared to commercially available products, and remains effective over 60 days, outperforming traditional products, particularly in maintaining its effectiveness in humid environments.

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Example 3: Study to determine the effectiveness of Exemplary Rodent Repellent Composition in shopping mall

The effectiveness of Exemplary Rodent Repellent Composition B obtained from Example 1 was determined by placing 20 cans of the rodent repellent composition at a food court area of 5,000 square feet in a single-floor shopping mall in Hong Kong for a period of 4 months. The design of

the study involved the monitoring of 13 shop units, where the repellent compositions are placed in a closed defence deployment area.

5 The granular compositions of the present disclosure were primarily placed on the open ceiling of the floor, with 16 cans placed on the ceiling passages connecting different restaurants and 4 cans placed in vacant shops.

The study has a duration of 150 days and consists of the following phrases: (i) a 30-day monitoring period for data collection, (ii) a 30-day repellent deployment period, (iii) a 30-day of control period (empty cans are deployed), (iv) a further 30-day repellent deployment period, and a further 30-day of control period (empty cans are deployed).

10 Rodent activities are determined by a number of factors during the study, including sightings, rodent feces, smell, rodent body oil traces, and new holes created by rodents and alarms generated by the fire alarm system due to rodent bites.

Findings from each of these phrases are reported as follows:

15 (i) Monitoring Phase (30 days): a number of complaints were received from two units, indicating significant rodent activity was observed.

(ii) Active Repellent Phase (60 days): During this phase, only 2 incidents of unusual rodent movements were reported and management office received no tenant complaints during this phrase, suggesting effective repellent action with >90% of efficacy.

20 (iii) Control Phase (60 Days): Rodent tracks were reported, indicating a return of rodent activity. Tenant complaints were also received by management office on a weekly basis.

25 The above study confirms that the rodent repellent composition of the present disclosure is able to provide a significantly large coverage (an average of 250 sq. ft. per device), as compared to existing products advertised to provide coverage of 8 sq. ft. per device; and is effective in deterring rodent from areas where the composition is placed.

Example 4: Long Term study of effectiveness of Exemplary Rodent Repellent Composition at a Construction Site

30 A testing method involving the use of baits, IoT sensors and infra-red cameras is adopted to determine the effectiveness of pest control, after initial field testing at a sportsground in Hong Kong. As described below, Exemplary Rodent Repellent Composition B obtained from Example

1 was found to be able to repel rodents at a construction site in Hong Kong for a period of over 14 months.

20 cans containing the rodent repellent composition obtained from Example 1 were placed across a 9,000 square feet construction site at Tuen Mun public estate in December 2022.

5 Rodent activity was measured by (i) the number of actual captured rodents, as well as (ii) observed rodent movement by IoT sensors and infra-red cameras, and number of bitten baits placed at designed locations.

Measurements were taken since November 2022 up until February 2024 and the results are demonstrated in Fig. 6. It can be seen that rodent activity significantly since the deployment of the rodent repellent composition of the present disclosure.

The repellent composition was found to be effective for of outdoor use, and a regular refill of every 30 days was sufficient to maintain potency of the natural oils. As shown, the tested area has been free from rodent for nearly 12 months.

The above embodiments are described by way of example only. Many variations are possible without departing from the scope of the disclosure as defined in the appended claims.

Although a variety of examples and other information was used to explain aspects within the scope of the appended claims, no limitation of the claims should be implied based on particular features or arrangements in such examples, as one of ordinary skill would be able to use these examples to derive a wide variety of implementations. Further and although some subject matter may have been described in language specific to examples of structural features and/or method steps, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to these described features or acts. For example, such functionality can be distributed differently or performed in components other than those identified herein. Rather, the described features and steps are disclosed as examples of components of systems and methods within the scope of the appended claims.

CLAIMS

1. A granular composition for the release of one or more volatile oils, comprising rubber granules carrying a hydrophobic component comprising at least one volatile oils.
- 5 2. The granular composition according to claim 1, wherein the hydrophobic component is on the rubber granules, or impregnated within the rubber granules.
3. The granular composition according to claim 1, wherein the release of one or more volatile oils is sustained over a duration of 30-60 days.
4. The granular composition according to claim 1, wherein the rubber granules are crumb rubber derived from a feedstock selected from rubber tyres, gaskets, belts, hoses.
- 10 5. The granular composition according to claim 1, wherein the rubber granules are sized between 1-10mm in diameter.
6. The granular composition according to claim 1, wherein the volatile oils are essential oils or synthetic oils.
- 15 7. The granular composition according to claim 1, wherein the volatile oils are essential oils selected from the group consisting of citronella oil, chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary oil, lavender oil, tea tree oil, neem oil, oregano oil, clove oil, cinnamon oil, thyme oil, garlic oil, wintergreen oil, lemongrass oil, lavender oil, lime oil, geranium oil, anise oil, angelica oil, basil oil, bay oil, bergamot oil, camphor oil, cananga oil, cardamom oil, caraway oil, cedar oil, cedarwood oil, Chamaecyparis obtusa oil, chamomile oil, cinnamon oil, citronella oil, clove oil, copaiba balsam oil, cumin oil, clove oil, coriander oil, dill oil, eucalyptus oil, fennel oil, garlic oil, geranium oil, grapefruit oil, ginger oil, guaiac oil, hiba oil, iris oil, Japanese mint oil, jasmine oil, lavender oil, lemon oil, lemongrass oil, linaloe oil, Lindera oil, mandarin oil, mint oil, neroli oil, onion oil, orange oil, oregano oil, patchouli oil, parsley oil, pepper oil, 25 peppermint oil, perilla oil, Peru balsam oil, petitgrain oil, pine oil, pine needle oil, rose oil, rosemary oil, sandalwood oil, spearmint oil, star anis oil, tangerine oil, tea seed oil, tea tree oil, thyme oil, tolu balsam oil, tuberose oil, turmeric oil, vetivert oil, western mint oil, wintergreen oil and any combination thereof.
- 30 8. The granular composition according to claim 1, wherein the hydrophobic component comprises one or more essential oils selected from the group consisting of citronella oil,

chili oil, peppermint oil, eucalyptus oil, lemongrass oil, cedarwood oil, rosemary Oil, lavender oil, tea tree oil.

- 5 9. The granular composition according to claim 1, wherein the hydrophobic component further comprises an agent selected from the group consisting of pheromones, odor-neutralizing agent, odor-masking agent, additive, stabilising agent, antimicrobial agent, UV-blocking agent, moisture control agent.
- 10 10. The granular composition according to claim 1, further comprising a nanoparticle component.
- 10 11. The granular composition according to claim 10, wherein the nanoparticle component comprises one or more metal oxides.
12. The granular composition according to claim 10, wherein the nanoparticle component comprises, in weight percentages:
- 15 5-11% titanium dioxide (TiO₂),
2-7% zinc oxide (ZnO),
10-15% fumed silica,
1-2% magnesium oxide (MgO),
1-2% calcium carbonate (CaCO₃),
0.5-1% aluminum oxide (Al₂O₃),
and 0.5-1% silicon dioxide (SiO₂).
- 20 13. The granular composition according to claim 10, wherein the nanoparticle component further comprises barium sulfate (BaSO₄), talc, or zeolites.
14. The granular composition according to claim 1, wherein the granular composition further comprising a stabilizer, an antioxidant or a catalyst.
- 25 15. The granular composition according to any one of claims 1-14 for use in a method of pest control.
16. The granular composition according to claim 15, wherein the volatile oil is a pest repellent.

17. The granular composition according to claim 15, wherein the volatile oil is a pest attractant.
18. An article comprising a container housing the granular composition according to claim 1.
- 5 19. The article according to claim 18, wherein the container is an aluminium can comprising a sealable aluminium lid with a plurality of apertures defined therein for transmission of vaporised volatile oils therethrough.
20. The article according to claim 19, wherein the aluminium lid is overlaid with a cellophane film or a cotton muslin fabric.
- 10 21. The article according to claim 18, wherein the container is a plastic bottle comprising a sealable plastic lid with a plurality of apertures defined therein for transmission of vaporised volatile oils therethrough.
22. A method of controlling pests by exposing the pests to the granular composition according to any one of claims claim 1-17 or the article according to any one of claims 18-21.
- 15 23. The method according to claim 22, wherein the pests are rodents, cockroaches, mosquitoes, bed bugs, fleas, ants, silverfish, firebrats, aphids, termites, weevils, beetles, mites, millipedes, centipedes, sowbugs, crickets, ants, flies, or spiders.
24. The method according to claim 22, wherein the pests are cockroaches, mosquitoes, bed bugs, or fleas.
- 20 25. The method according to claim 22, wherein the pests are rodents.
26. The method according to any one of claims 22-25, further comprises refilling the article with one or more volatile oils.
27. A method of preparing a composition, comprising:
- 25 - mixing rubber granules of 1-10mm with a hydrophobic component comprising one or more volatile oils;
- optionally, adding and mixing a nanoparticle component.