

DEVICES AND METHODS FOR SPRAYING INSECTICIDE WITH ULTRASONIC MISTERS

[0001] This application claims priority to our copending US Provisional patent application with the serial number 63/547,530, which was filed 11/6/2023, and which is incorporated by reference herein.

Field of the Invention

[0002] The field of the invention is fog machines and insecticide spraying, especially as they relate to using ultrasonic transducers to adjust the density of the output fog and thus the height and spread of the output fog to repel or kill mosquitoes such as *Aedes aegypti* and *Culex spec.* near the ground.

Background of the Invention

[0003] The background description includes information that may be useful in understanding the present disclosure. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

[0004] All publications and patent applications herein are incorporated by reference to the same extent as if each individual publication or patent application were specifically and individually indicated to be incorporated by reference. Where a definition or use of a term in an incorporated reference is inconsistent or contrary to the definition of that term provided herein, the definition of that term provided herein applies and the definition of that term in the reference does not apply.

[0005] Among other genera and species of insects, *Aedes aegypti* (ankle biter mosquito), *Culex spec.* (common mosquito), and *Anopheles spec.* (marsh mosquito) are the most significant vectors for a number of virus-borne diseases such as West Nile fever, dengue fever, chikungunya virus disease, Zika fever, Mayaro fever, and yellow fever, and parasitic diseases such as malaria. In addition to these serious health risks, mosquito bites from these species are also characterized by a pruritic rash and localized swelling, which may lead to secondary infections, going well beyond simple discomfort. Notably, however, despite the prevalence and geographically wide distribution of these mosquitoes, effective methods of deterring or

exterminating, especially in a residential setting are not readily available, despite various marketing messages claiming otherwise. For example, CO₂- or UV-based traps will attract a variety of insects but are generally limited to a small area and/or airborne mosquitoes. Insecticide sprays as well as the fumes of hand-held or backpack foggers are readily dispersed in the environment, particularly in an outdoors setting.

[0006] To avoid the shortcomings of trapping insects, fog machines have been used to repel insects as is for example described in US 2,662,332. Here, an insecticide is vaporized in a heating chamber and the resultant vapor is then fed into an airstream driven by a blower where the airstream is expelled into the surrounding environment. Similarly, US 7,712,249 and US 8,296,993 teach ultrasonic repellent humidifiers forming a repellent vapor that is expelled into the surrounding environment. While conceptually simple and portable for domestic use, the insecticide vapor will quickly dissipate into the ambient atmosphere. In still further examples, fog machines such as disclosed in CN 202635410U use gravity to mix water and calcium oxide to produce high heat and evaporate an insecticide. However, due to the high temperatures, the so generated fog rises quickly and once more dissipates into the environment. Such lack of spatial control is especially disadvantageous where the insects are ground dwelling insects or insects that rest on or near ground foliage (*e.g.*, grass blades) as is the case with *Aedes aegypti* and *Culex spec.* While these mosquitoes hatch from stagnant water and can travel at least some distance, they will spend most of their life near or on the ground before hunting for a blood meal. As such, rapidly dissipating insecticides will be largely ineffective for repelling or exterminating these pests.

[0007] On the other hand, in stage and concert settings, specialized fog machines have been developed that can produce significant quantities of theatrical fog that can be directed towards the ground and that will not readily dissipate from the ground as is disclosed, for example, in US 11,154,791 and US 2018/0221785. Here, a fog stream that is generated from a conventional fogger is mixed with ultrasonically generated water droplets using a baffle assembly to thereby increase the density of the fog. However, such fog machines are typically rather complex, often require professional set-up and operation, and are generally cost-prohibitive for residential use. Moreover, due to their particular use in stage and theater environments, these devices are not used or even intended for insecticide or insect repellent dispersal.

[0008] Thus, even though various fog generating devices and methods are known in the art, all or almost all of them suffer from various disadvantages. Consequently, there is still a need to

provide improved devices and methods that allow for generation of insecticide- or repellent-laden ground fog that can be deployed in residential or agricultural settings without requiring complex equipment or trained personnel.

Summary of The Invention

[0009] The inventors have discovered devices and methods that allow for generation of a ground fog that contains an insect repellent and/or insecticide that advantageously blankets an area of interest with a dense and persistent fog to so repel or exterminate ground dwelling insects, and especially adult mosquitoes such as *Aedes aegypti*, *Culex spec.*, and *Anopheles spec.* Preferably, the fog is generated in a portable unit, remains proximal to the ground and can be dispersed from one or more output ports that may or may not be coupled to an elongate guide conduit with optional openings and/or one or more distribution pods.

[0010] In one aspect of the inventive subject matter, method of temporarily repelling or exterminating mosquitoes in an area of interest that includes the steps of generating a primary fog from a fogging fluid that includes an insecticide or an insect repellent; exposing the primary fog to an ultrasonic mist to thereby generate a secondary fog that contains the insecticide or the insect repellent, wherein the secondary fog has a density that is greater than a density of the primary fog; and directing the secondary fog to the area of interest, wherein the area of interest is at least 25 m², wherein the secondary fog distributes over the area of interest to a height of no more than 1 m; and wherein the secondary fog is maintained in the area of interest for at least 1 minute, thereby repelling or exterminating the mosquitoes (*e.g.*, *Aedes aegypti*, *Culex spec.*, or *Anopheles spec.*).

[0011] Typically, but not necessarily, the secondary fog has a persistence of at least 2 minutes, and/or the majority of the secondary fog settles in the area of interest. It is further generally contemplated that the primary fog is generated using thermal fogging. Therefore, the primary fog may comprise propylene glycol, vegetable glycerin, and/or glycerol. Where desired, the primary fog may also comprise a humectant and/or a detergent.

[0012] In some embodiments, it is contemplated that the insecticide is an adulticide. In further embodiments, the insecticide is a natural insecticide (*e.g.*, a natural pyrethrin or an essential oil), while in still further embodiments the insecticide is a synthetic insecticide (*e.g.*, an organophosphate, a synthetic pyrethroid, a neonicotinoid, a picardin, a permethrin, an allethrin, a carbamate, or an organochlorine). In further contemplated embodiments, the ultrasonic mist

is generated by one or more fixed-distance transducers, which for example, may be coupled to a floating frame that floats on an aqueous medium. As will be readily appreciated, the ultrasonic mist will comprise size- and/or density-controlled mist particles (typically water particles), wherein the size and/or density of the mist particles is controlled by a power and/or frequency controller that is operationally coupled to an ultrasound transducer.

[0013] Moreover, it is contemplated that the secondary fog is directed by one or more exit nozzles. Where desired, the secondary fog may also be directed by a guide channel extending at least 3 m away from a location of the secondary fog, wherein the guide channel may have a plurality of openings that allow for partial escape of the secondary fog. In addition, one or more distribution pods may be coupled to the guide channel where the pods are configured to distribute the secondary fog away from the distribution pod.

[0014] As will be readily appreciated, the area of interest may be a residential area (*e.g.*, front yard, back yard, bedroom, a waiting room, or a community assembly area) or an agricultural area (*e.g.*, an orchard, a vineyard, and a berry growing operation). In most instances, the secondary fog will be directed to the area of interest for less than 10 minutes. Preferably, the primary fog and the secondary fog are produced in a single portable container, and the primary fog and the secondary fog are produced using a portable energy source. Most typically, the secondary fog has a temperature that is within 10 °C of ambient temperature, thereby stabilizing the fog and enabling the fog to remain in the area of interest without rising.

[0015] Therefore, the inventors also contemplate an insecticide fogging device that comprises a housing at least partially enclosing a mister, a fogging insecticide reservoir, and an ultrasonic mister reservoir. In such devices, the fogging insecticide reservoir is fluidly coupled to the mister, and the mister is configured to generate a primary fog comprising a fogging insecticide and to deliver the primary fog to the ultrasonic mister reservoir. The ultrasonic mister reservoir is configured to retain an aqueous solution and an ultrasonic transducer unit, wherein the ultrasonic transducer unit is configured to increase humidity above the aqueous solution and to increase density of the primary fog, thereby generating a secondary fog. The ultrasonic transducer unit is further preferably configured to maintain a fixed distance between a vibrating surface of a transducer and a surface of the aqueous solution, and the housing comprises an output port for release of the secondary fog.

[0016] In some embodiments, the housing is configured as a portable container and/or the mister comprises a thermal fogger. Moreover, it is contemplated that the ultrasonic mister reservoir has a volume sufficient to (1) retain at least 5 liter of the aqueous solution, and (2) allow for an increase in density between the primary fog and the secondary fog of at least 10%. Additionally, or alternatively, it is contemplated that the ultrasonic transducer unit is configured to float in the aqueous solution and contains at least one ultrasonic transducer coupled to the unit such that the ultrasonic transducer maintains a fixed distance from a surface of the aqueous solution.

[0017] In yet further embodiments, the fogging device further comprises a control unit that is operationally coupled to the mister and/or the ultrasonic transducer. For example, the control unit may be configured to measure and/or adjust (1) a temperature in the housing, (2) a flow rate of insecticide from the fogging insecticide reservoir to the mister, (3) a rate of misting by the mister, and/or (4) activity of the transducer. Additionally, or alternatively, the fogging device may comprise an interface configured to allow an operator to provide an input to the control unit. For example, the interface may be configured to allow the operator to specify a desired height of the secondary fog above ground, and/or may be configured to allow an operator to specify a desired insecticide concentration of the secondary fog.

[0018] Where desired, the fogging device may further comprise an elongate guide conduit coupled to the output port, wherein the guide channel optionally has a plurality of openings that allow for partial escape of the secondary fog along a length of the guide channel. Moreover, contemplated fogging devices may further include a distribution pod coupled to the guide channel and configured to distribute the secondary fog away from the distribution pod.

[0019] Various objects, features, aspects, and advantages will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing.

Brief Description of The Drawing

[0020] **FIG.1** is a schematic illustration of an exemplary fogging device according to the inventive subject matter.

[0021] **FIG.2** is a schematic illustration of an exemplary fogging device with an elongate guide conduit and distribution pod according to the inventive subject matter.

Detailed Description

[0022] The inventors have discovered devices and methods for insecticide fogging that convert a primary insecticide fog into a denser secondary fog to so generate a ground fog that has reduced or even entirely abolished tendency to rise from the ground. Indeed, the ground fog generated using the systems and methods contemplated herein will remain at very low levels and is able to persist over extended periods of time. As will be readily appreciated, such ground fog is particularly desirable where the insects predominantly reside or rest on or near the ground as is, for example, the case with various mosquito species that are vectors of serious diseases.

[0023] As is described in more detail below, the primary fog is typically generated by heating and vaporizing a carrier fluid (*e.g.*, aqueous propylene glycol) that contains an insecticide or insect repellent, where the vaporized fluid subsequently condenses into a fog that includes the insecticide or insect repellent. The so generated fog is then fed into a highly humidified section in which small water particles (*e.g.*, generated by ultrasonic misting) bind to or are absorbed by the fog particles to yield a heavier and denser secondary fog. By using an appropriate primary fog carrier fluid, primary fog production rate, and sonication parameters, the characteristics of the secondary fog can be tuned to a desired 'hang time' (*i.e.*, time measured from generation of the secondary fog to settling or dispersion of the fog) and distribution height, thereby allowing targeting of adult mosquitoes. Moreover, due to the concentrated secondary fog treatment, mosquitoes can be repelled or killed in a very short time to so at least temporarily render an area of interest free of ground dwelling insects.

[0024] For example, **FIG.1** schematically shows an insecticide fogging device 100 in which a mister 110, a fogging insecticide reservoir 112, and an ultrasonic mister reservoir 104 are contained in a housing 101. Here the mister 110 generates primary fog 114 that contains a fogging insecticide and that is delivered to the ultrasonic mister reservoir 104 that contains aqueous solution 106. An ultrasonic transducer unit 140 is coupled to a floating frame 141 and has one or more (fixed distance) transducers 142. In operation, the ultrasonic transducer unit increases humidity above the aqueous solution by forming small water particles 108 that merge or bind to the primary fog particles to so increase the density of the primary fog, thereby generating secondary fog 116. Secondary fog 116 then exits the housing via output port 109. In the example device of FIG.1, operation of the components is controlled by control unit 120 and/or user interface 122, and power is supplied by portable energy source 130 (typically a rechargeable battery).

[0025] In most residential uses it is contemplated that the fogging device will generate sufficient fog to treat an area of interest such as a back patio, a front yard, etc. However, non-contiguous areas of interest (*e.g.*, sections of a back yard) or areas of interest at different elevation (*e.g.*, elevated BBQ island, elevated flower beds, etc.) or areas of unusual geometry (*e.g.*, extended rows of grass or side yard adjacent to a building) can also be treated using the devices contemplated herein as is exemplarily and schematically shown in **FIG.2**. Here, fogging device 200 is coupled to an elongate guide conduit 240 (*e.g.*, flexible and collapsible cylindrical conduit with 10 cm diameter) at a first output port of the device, and the elongate guide conduit guides the secondary fog to a distribution pod 250 that will typically have one or more openings (which may be individually controllable and/or steerable) through which the secondary fog 252 can then pass to the remote area of interest. In a like manner, an elongate guide conduit 240 may also have one or more openings along its longitudinal axis to so distribute portions of the secondary fog 242 along the length of the guide channel.

[0026] Of course, it should be appreciated that contemplated devices and methods may also use various alternative configurations, including those where the primary fog generation is at least somewhat decoupled from the secondary fog generation. For example, such devices may comprise a housing that has a primary and secondary chamber. Here, the primary chamber may contain a mister that is fluidly coupled to a fogging insecticide reservoir to generate the primary fog that will be made up of fogging insecticide particles. The mister is then fluidly coupled (*e.g.*, via a dedicated primary fog carrying conduit, or by connecting the chambers directly) to the secondary chamber that may contain a reservoir configured to retain an aqueous solution and an ultrasonic transducer. As will be readily appreciated, the ultrasonic transducer is configured to acoustically couple with the aqueous solution to so generate humidity in the secondary chamber, which is also configured to allow the primary fog to collect humidity therein to so increase the density of the primary fog and thereby generate a secondary fog. As before, the secondary chamber also will typically include one or more an output ports for release of the secondary fog.

[0027] With respect to the primary fog it is typically preferred that the primary fog is thermally generated from a fogging fluid, for example, via a thermal element of a commercially available heating core for vaporization of fog fluids. As will be readily appreciated, such heating cores may be sized and dimensioned to accommodate a particular need for fog volume and duration of fog generation. Therefore, in most residential and small industrial situations, the heating

core may be rated at about 400 W, such as between 250 W and 400 W, or between 300 W and 500 W, or between 500 W and 800 W, or as high as 1,200 W and even higher (*e.g.*, for larger industrial or agricultural use). Alternatively, the thermal generation may also rely on propane or other hydrocarbon fuel, particularly for generation of larger quantities and/or outdoor use. In yet other embodiments, it is contemplated that the primary fog may also be generated using non-thermal methods, including atomizers, spray nozzles, etc. Depending on the particular manner of generating the primary fog, it is contemplated that the droplet size may vary considerably. However, it is generally preferred that the primary fog droplet size will be between 0.5 and 5.0 micrometer, such as between 0.5 and 2.0 micrometer, or between 1 and 5 micrometer, or between 3 and 9 micrometer.

[0028] Still further, it is contemplated that the primary fog is generated from an aqueous solution that will typically include one or more non-aqueous components, and especially contemplated non-aqueous components include propylene glycol, vegetable glycerin, and/or glycerol. In addition, it should be noted that the aqueous solution may further comprises a humectant and/or a detergent to so enhance or modulate the interaction with the ultrasonic (or otherwise generated) mist. Most typically, the predominant component in the aqueous solution will be water (*e.g.*, between 50% and 60%, or between 55% and 70%, or between 60% and 80%, and even higher), while the remaining quantity is made up by propylene glycol, vegetable glycerin, and/or glycerol, and optionally a humectant and/or a detergent (typically present in an amount of between 0.1% to 1, or between 1% and 3%, or between 3% and 5%, and in some cases even higher).

[0029] Similarly, it should be noted that the secondary fog can be created in a variety of manners so long as the primary fog is exposed to a high-humidity environment to thereby allow the primary fog to absorb or bind water particles in a confined space before the secondary fog is being released into the environment. Preferably, exposure is performed at a relatively low temperature (typically within +/- 10 °C, or within +/- 8 °C, or within +/- 6 °C) of the ambient temperature. In other embodiments, and especially where the ambient temperature is relatively high (*e.g.*, at least 25 °C, or at least 27 °C, or at least 30 °C), exposure can be performed at significantly lower temperatures such as at about 4-10 °C, or at about 10-15 °C, or at about 15-20 °C). Therefore, it should be appreciated that the secondary fog will have a low temperature that is typically at or near ambient temperature (and in some cases even moderately below).

Nevertheless, and contrary to most other fog generators, the so generated secondary fog will remain near the ground due to the increased density of the fog particle.

[0030] Of course, it should be appreciated that the high-humidity environment can be produced in a variety of manners to form the secondary fog such as with atomizers and/or spray nozzles. However, it is particularly preferred that the high-humidity environment is generated using an ultrasonic mister. For example, suitable ultrasonic transducer units will include multiple ultrasonic transducers (*e.g.*, between 2 and 20) and will operate at a typical power consumption of between 100 W-300 W, or between 200 W and 500 W, or between 400 W and 800 W (*e.g.*, 10 transducers, unit operating at 350-400 W). Viewed from a different perspective, individual ultrasonic transducers will typically operate at a power of 20-40W at a frequency of about 40 kHz. Multiple ultrasonic transducers can then be placed into a ultrasonic transducer unit for generation of the high-humidity environment.

[0031] Regardless of the specific manner of generating the high-humidity environment it is generally preferred that the high-humidity environment contains a plurality of water mist particles having a droplet size of between about 200-400 nm, or 300-600 nm, or between 500-800 nm, or between 750-1,000 nm, or between 850-1,250 nm, with larger sizes of these ranges generally preferred. Where ultrasonic transducers are employed, it is especially preferred (but not necessarily so) that the transducer unit comprises float or other buoyant structure that positions the ultrasonic transducers at a fixed distance relative to the water surface. In that context, it should be especially appreciated that such and other fixed-distance arrangements greatly simplifies the build and advantageously removes a significant variable that affects the secondary fog height.

[0032] Alternatively, where a transducer unit is in a fixed position relative to the housing, it is contemplated that level control for the water surface relative to transducer element(s) can be done using a pump that actively maintains a desired water level (in response to a water level sensor and control circuit) to so once more achieve a fixed distance. Likewise, a 'bird feeder' technology may be employed for water level control in which a partially submerged feed conduit (attached to a storage reservoir) has an opening, and in which the lower open end of the conduit terminates in the mister reservoir. As the water level in the reservoir drops below the opening, water flows from the storage reservoir into the mister reservoir until the opening is once more covered. In still another example, a control float and feed valve may be used to maintain water levels at a substantially constant level relative to the ultrasonic transducer.

[0033] Most typically, suitable water quantities for the ultrasonic mister reservoir are typically between 1 liter and 10 liter, or between 10 liter and 25 liter, or even larger for stationary units. Alternatively, water may also be provided in a continuous supply from a hose, a larger feed tank, etc.

[0034] As will be readily appreciated, various parameters of the secondary fog may be easily controlled, and among other options, the feed rate of primary fog and the humidity in the mister reservoir present simple options. Most typically, and depending on the particular configuration and operation, contemplated devices will have a secondary fog output of between 5 m³/min and 5 m³/min, or between 10 m³/min and 25 m³/min, or between 25 m³/min and 50 m³/min, or between 50 m³/min and 100 m³/min, or between 100 m³/min and 250 m³/min, and even higher. Typical density differentials between primary and secondary fog will be at least 4%, at least 10%, at least 20%, and even higher, and the exact density of the secondary fog will be determined by the density of the primary fog, the flow rate of the primary fog, and the operational parameters of the ultrasonic mister (secondary fog density increases with increasing humidity loading of the primary fog). Consequently, it should be appreciated that the height of the fog, when released from the fogging device, can be controlled by these simple operational parameters.

[0035] It is further contemplated that the primary fog may be passively moved to the ultrasonic mister reservoir or may be moved using a fan or blower. Similarly, the secondary fog can be passively released from ultrasonic mister reservoir or actively using a blower or booster fan. Moreover, it should be appreciated that the secondary fog release can be into the environment or into an guide structure such as an elongate guide conduit that may have openings along its length or that may be coupled to a distribution pod from which the secondary fog is then released. Most typically, but not necessarily, the elongate guide conduit will be a flexible (and preferably collapsible) hose with an inner diameter of at least 2 cm, or at least 5 cm, or at least 10 cm, and even larger, and will have a length of at least 1 m, or at least 5 m, or at least 10 m, and for agricultural use between 5 and 50 m, and even longer.

[0036] As noted earlier, the fog height upon release can be controlled in a variety of manners (alone or in combination), and suitable manners include the number of ultrasonic transducers in the transducer unit that are in operation, the operational voltage applied to the transducers, the operational current supplied to the transducers, and the fog volume going through the humidification chamber. Thus, humidity control in the humidity chamber (*e.g.*, via ultrasonic

humidification) advantageously provides for control of a desired fog density, and with that a desired height of a fog emitted from the humidity chamber. As will be readily appreciated, the flow rate and dimensions of contemplated devices will further affect the fog spread, and it is generally contemplated that the fog spread into the area of interest in domestic use devices will be at least 10-25 m², or at least 20-50 m², or at least 30-100 m², and in agricultural use devices between 1,000 and 5,000 m² and even higher.

[0037] Most typically, contemplated devices will be operated to generate an adjustable secondary fog height and suitable heights will be no more than 100 cm, or no more than 75 cm, or no more than 50 cm, or no more than 30 cm, or no more than 20 cm. Therefore, secondary fog heights of between 1 and 5 cm, or between 3 and 10 cm, or between 5 and 15 cm are particularly contemplated. Moreover, it should be appreciated that due to the homogeneity of the secondary fog particles, no more than 30%, or no more than 25%, or no more than 20%, or no more than 15%, or no more than 10% of the secondary fog will rise above a desired height. In addition, the inventors noted that the so generated secondary fog had a relatively long persistence in the area of interest. Indeed, the time to dissipation or condensation of the secondary fog in an area of interest at 22 °C was at least 1 min, or at least 2 min, or at least 4 min, or at least 8 min, and in some cases even longer. Moreover, and viewed from a different perspective, the majority (e.g., at least 55%, or at least 65%, or at least 75%, or at least 85%, or at least 90%) of the secondary fog settled to the ground or evaporated in the area of interest without loss due to rising of the fog above 1 m.

[0038] In view of these advantages, use of the devices and methods presented herein especially applies to residential and even industrial pest control uses where the target pest dwells on or near the ground. Most significantly, it should be appreciated that numerous blood sucking mosquitoes that transmit viral and parasitic diseases such as *Aedes aegypti*, *Culex spec.*, or *Anopheles spec.* will rest after emerging from the pupal stage on or near the ground (e.g., on grass blades) before going on the hunt for a blood meal. It is in that stage that contemplated devices and methods will provide selective repellent and/or insecticidal action without requiring eradication of the earlier life cycle stages (i.e., egg, larva, pupa) that play an important role in the ecology of other species.

[0039] Therefore, especially contemplated devices and methods will use a fogging fluid that includes an insect repellent or insecticide, and in some cases even a mosquito adulticide. For example, suitable insecticides or insect repellents include various organophosphates (e.g.,

malathion, naled, fenitrothion, etc.), various synthetic pyrethroids (*e.g.*, deltamethrin, permethrin, sumithrin, cypermethrin, lambda-cyhalothrin), neonicotinoids, permethrins, a carbamate (*e.g.*, propoxur, bendiocarb), an organochlorine (*e.g.*, DDT), picaridin, allethrin, etc. Alternatively, or additionally, natural repellents and insecticides may also be used and include natural pyrethrins (*e.g.*, from chrysanthemum extracts), one or more essential oils (*e.g.*, from orange, eucalyptus, citronella, lemon eucalyptus, garlic, sweet basil, etc.), capsaicin and/or capsaicin analogs. Especially contemplated adulticides include pyrethroids (*e.g.*, permethrin, resmethrin, deltamethrin, Cypermethrin, Allethrin, and sumithrin), Esbiothrin, malathione, prallethrin, and etofenprox. In still further contemplated aspects, and especially where an even denser secondary fog is desired, the fogging insecticide and/or the aqueous solution may provide denser compounds such as SF₆, C₂F₆, and/or CO₂.

[0040] The inventors still further contemplate that the fogging devices may include a control unit that is operationally coupled to the mister and/or the ultrasonic transducer. In some examples, the control unit is configured to measure and/or adjust the temperature in the housing, the flow rate of insecticide to the (thermal) mister, the flow rate of an optionally second fluid to the mister, the rate of misting, and/or activity of the ultrasonic transducer(s). For example, a temperature control unit may sit within the primary chamber. Such temperature control unit may be configured to measure and adjust the temperature of the fogging insecticide in the fogging insecticide reservoir before the fogging insecticide is conveyed to the secondary chamber by the mister. Additionally, the temperature control unit may be coupled to the mister by one or more wires, but in other embodiments, the coupling is wireless. In still other embodiments, the mister can be powered by line voltage, however it may also be powered by a battery.

[0041] In preferred embodiments, to allow an operator to provide input to the control unit, the inventors contemplate that the fog machine includes an interface usable by the operator. The interface may be as simple as a panel of knobs, buttons, and sliders, or may include a digital screen, or a Bluetooth or Wi-Fi interface for remote control. The interface may alternatively be a wireless or wired remote allowing the operator to communicate with the control unit by pressing buttons. It is also contemplated that the interface allows the operator to turn the fog machine on or off. However, in other embodiments, the fog machine may turn on when connected to a power source and turn off when disconnected to the power source. The inventors contemplate that an important, yet optional feature of the interface is to allow the operator to a

desired height of the secondary fog above ground. The interface may also provide the option to specify the spread of the fog. Additionally, the interface may be configured to allow the operator to specify a desired insecticide concentration of the secondary fog. As an example, and not intended to limit the disclosed subject matter, the operator may set the desired insecticide concentration to “high” when using the fog machine in an area with high amounts of harmful insects, and alternatively the operator may set the desired insecticide concentration to “low” when spraying a relatively small area of crops.

[0042] Moreover, the control unit may further be configured to allow the operator to control the operating frequency, amplitude, timing and/or intensity of the ultrasonic transducer’s activity. It should be noted that the ultrasonic transducer being acoustically coupled to the aqueous solution may include, but is not limited to, the ultrasonic transducer being immersed in the aqueous solution while sitting at the bottom of the reservoir, at a side of the reservoir, or at the top of the reservoir. However, in other embodiments, an acoustic intermediary, such as a horn or waveguide, may be positioned between the ultrasonic transducer and the reservoir. In some instances, multiple ultrasonic transducers may be coupled to the reservoir, and some or all of the transducers may be turned on or off based on input from the operator.

[0043] In still further contemplated uses of the devices and methods presented herein, it is contemplated that the fogging devices presented herein may also be configured to wet crops with insecticide. This may be particularly advantageous in situations where it is challenging to quickly spray insecticide over a large area of crops, especially when targeting the undersides of crops. Moreover, plant treatment may be effected at the base and/or root without affecting the stem, foliage, and/or value products above ground such as fruit, berries, flowers, etc. Due to the fog machine releasing a denser insecticide fog, the fog can effectively remain closer to the ground and, as a result, target the undersides of crops more efficiently. However, it should be noted that the contemplated invention also allows fog to reach crops higher above the ground, such as where an operator specifies that the fog should be higher above the ground and thus less dense. In either scenario, the inventive subject matter allows the operator to specify the height of the fog in view of different crops with different heights and properties. In some embodiments, the fog machine may be coupled to a remote-controlled vehicle, an autonomous vehicle, a drone, or a plane. In these instances, the fog machine may or may not be used to spray crops. However, it may be beneficial to use the contemplated fog machine attached to

one or more of the mentioned vehicles when spraying crops, especially as it relates to fogging entire fields of crops.

[0044] Moreover, contemplated devices and methods may also be suitable for domestic or industrial flea treatment, for treatment of carpets, termite, roach, or ant infestations, etc. In addition, it is contemplated that the ground fog may also be suitable for extermination of underground rodents and pests such as rats, mice, gophers that may dwell in burrows or underground utility pipe and ductwork.

[0045] In still further contemplated embodiments, it should be appreciated that numerous fluids other than insecticide solutions may be used with the devices and methods presented herein. For example, the fluid that is converted into the primary and/or secondary fog may contain instead of an insecticide a functional or sensory ingredient to achieve a specific purpose. For example, suitable alternatives to insecticides include flavorants or aromatic compounds and compound mixtures (which may be individual compounds or complex mixtures such as extracts or fractions of plant a material). Therefore, suitable functional ingredients include deodorizers, herbicides, fungicides, antibacterial agents, bug-, snail-, rodent-, or game-repellants, pheromones, fertilizers (and especially those that are applied to foliage), optically active ingredients (*e.g.*, fluorescent or luminescent compounds), etc. Suitable flavorants or aromatic compounds include plant extracts such as garlic extracts, citronella extracts, extracts from other culinary aromatic plants, and individual aromatic compounds such as terpenoid compounds, etc., and still further contemplated ingredients include one or more enzymes with a desired functionality (*e.g.*, deodorizing, lipase, urease, etc.) Moreover, it should be appreciated that the functional and/or sensory ingredient may be part of the fluid that is used for the primary fog and/or part of the fluid that is used to produce the secondary fog.

[0046] For better maintenance and ease of use, the inventors also contemplate that the fogging devices may include an input port fluidly coupled to the fogging insecticide reservoir and configured to allow an operator to refill the fogging insecticide reservoir. In some instances, this input port may be a port allowing the operator to pour liquid through to fill the fogging insecticide reservoir. However, the input port may alternatively be designed as a socket that accommodates a disposable cartridge or container of insecticide. This cartridge or container can be easily removed and replaced with a new cartridge or container when needed. As will be readily appreciated, any component of the contemplated fog machine may be configured as a removable and replaceable or a refillable component. For example, the ultrasonic misting

reservoir may include an input port allowing an operator to refill or change the contents of the aqueous solution.

[0047] The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (*e.g.*, “such as”) provided with respect to certain embodiments herein is intended merely to better illuminate the full scope of the present disclosure and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the claimed invention.

[0048] It should be apparent to those skilled in the art that many more modifications besides those already described are possible without departing from the full scope of the concepts disclosed herein. The disclosed subject matter, therefore, is not to be restricted except in the scope of the appended claims. Moreover, in interpreting both the specification and the claims, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms “comprises” and “comprising” should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Where the specification claims refers to at least one of something selected from the group consisting of A, B, C and N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc.

CLAIMS

What is claimed is:

1. A method of temporarily repelling or exterminating mosquitoes in an area of interest, the method comprising:
 - generating a primary fog from a fogging fluid that includes an insecticide or an insect repellent;
 - exposing the primary fog to an ultrasonic mist to thereby generate a secondary fog that contains the insecticide or the insect repellent, wherein the secondary fog has a density that is greater than a density of the primary fog; and
 - directing the secondary fog to the area of interest, wherein the area of interest is at least 25 m², wherein the secondary fog distributes over the area of interest to a height of no more than 1 m; andwherein the secondary fog is maintained in the area of interest for at least 1 minute, thereby repelling or exterminating the mosquitoes.
2. The method of claim 1, wherein the secondary fog has a persistence of at least 2 minutes.
3. The method of claim 1, wherein the majority of the secondary fog settles in the area of interest.
4. The method of claim 1, wherein the primary fog is generated using thermal fogging.
5. The method of claim 1, wherein the primary fog comprises propylene glycol, vegetable glycerin or glycerol.
6. The method of claim 1, wherein the primary fog further comprises a humectant and/or a detergent.
7. The method of claim 1, wherein the insecticide is an adulticide.
8. The method of claim 1, wherein the insecticide is a natural insecticide selected from the group consisting of a natural pyrethrin, capsaicin, or an essential oil.
9. The method of claim 1, wherein the insecticide is a synthetic insecticide selected from the group consisting of an organophosphate, a synthetic capsaicin, a synthetic pyrethroid, a neonicotinoid, a picardin, a permethrin, an allethrin, a carbamate, and an organochlorine.

10. The method of claim 1, wherein the ultrasonic mist is generated by one or more fixed-distance transducers.
11. The method of claim 10, wherein the fixed-distance transducers are coupled to a floating frame that floats on an aqueous medium.
12. The method of claim 1, wherein the ultrasonic mist comprises size- and/or density-controlled mist particles.
13. The method of claim 12, wherein the size and/or density of the mist particles is controlled by a power and/or frequency controller that is operationally coupled to an ultrasound transducer.
14. The method of claim 1, wherein the secondary fog is directed by an exit nozzle.
15. The method of claim 1, wherein the secondary fog is directed by a guide channel extending at least 3 m away from a location of the secondary fog, wherein the guide channel has a plurality of openings that allow for partial escape of the secondary fog.
16. The method of claim 1, further comprising a distribution pod coupled to the guide channel and configured to distribute the secondary fog away from the distribution pod.
17. The method of claim 1, wherein the area of interest is a residential area selected from the group consisting of a front yard, a back yard, a bedroom, a waiting room, or a community assembly area.
18. The method of claim 1, wherein the area of interest is an agricultural area selected from the group consisting of an orchard, a vineyard, and a berry growing operation.
19. The method of claim 1, wherein the secondary fog is directed to the area of interest for less than 10 minutes.
20. The method of claim 1, wherein the mosquito is *Aedes aegypti*, *Culex spec.*, or *Anopheles spec.*
21. The method of claim 1, wherein the primary fog and the secondary fog are produced in a single portable container.

22. The method of claim 21, wherein the primary fog and the secondary fog are produced using a portable energy source.
23. The method of claim 1, wherein the secondary fog has a temperature that is within 10 °C of ambient temperature.
24. An insecticide fogging device, comprising:
a housing at least partially enclosing a mister, a fogging insecticide reservoir, and an ultrasonic mister reservoir;
wherein the fogging insecticide reservoir is fluidly coupled to the mister, and wherein the mister is configured to generate a primary fog comprising a fogging insecticide and to deliver the primary fog to the ultrasonic mister reservoir;
wherein the ultrasonic mister reservoir is configured to retain an aqueous solution and an ultrasonic transducer unit;
wherein the ultrasonic transducer unit is configured to increase humidity above the aqueous solution and to increase density of the primary fog, thereby generating a secondary fog;
wherein the ultrasonic transducer unit is further configured to maintain a fixed distance between a vibrating surface of a transducer and a surface of the aqueous solution; and
wherein the housing comprises an output port for release of the secondary fog.
25. The fogging device of claim 24, wherein the housing is configured as a portable container.
26. The fogging device of claim 24, wherein the mister comprises a thermal fogger.
27. The fogging device of claim 24, wherein the ultrasonic mister reservoir has a volume sufficient to (1) retain at least 5 liter of the aqueous solution, and (2) allow for an increase in density between the primary fog and the secondary fog of at least 10%.
28. The fogging device of claim 24, wherein the ultrasonic transducer unit is configured to float in the aqueous solution and contains at least one ultrasonic transducer coupled to the unit such that the ultrasonic transducer maintains a fixed distance from a surface of the aqueous solution.

29. The fogging device of claim 24, further comprising a control unit that is operationally coupled to the mister and/or the ultrasonic transducer.
30. The fogging device of claim 29, wherein the control unit is further configured to measure and/or adjust (1) a temperature in the housing, (2) a flow rate of insecticide from the fogging insecticide reservoir to the mister, (3) a rate of misting by the mister, and/or (4) activity of the transducer.
31. The fogging device of claim 29, further comprising an interface configured to allow an operator to provide an input to the control unit.
32. The fogging device of claim 31, wherein the interface is configured to allow the operator to specify a desired height of the secondary fog above ground.
33. The fogging device of claim 31, wherein the interface is configured to allow an operator to specify a desired insecticide concentration of the secondary fog.
34. The fogging device of claim 24, further comprising an elongate guide conduit coupled to the output port, wherein the guide channel optionally has a plurality of openings that allow for partial escape of the secondary fog along a length of the guide channel.
35. The fogging device of claim 34, further comprising a distribution pod coupled to the guide channel and configured to distribute the secondary fog away from the distribution pod.