

APPARATUS AND DEVICE FOR GENERATING NEGATIVE AIR IONS FROM PLANTS

Cross Reference to Related Application(s)

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The present invention claims the benefit of Singapore Patent Application No. 10201801988Y filed on 9 March 2018, which is incorporated in its entirety by reference herein.

10 Technical Field

The present invention generally relates to an apparatus and a device for generating negative air ions from plants. More particularly, the present invention describes various embodiments of an apparatus for generating negative air ions from plants, as well as
15 a portable device for use with plants to generate negative air ions from the plants.

Background

There are haze pollutions in many parts of the world, especially in Southeast Asia, due
20 to forest fires and other air pollutants. People exposed to haze may suffer from haze-related illnesses and people often have to take some actions when indoor pollutants reach to unhealthy, very unhealthy, or even hazardous levels according to the Pollutant Standards Index (PSI). Although air purifiers can be used to reduce the PSI in indoor environments, not everyone is able to afford them and some public places,
25 e.g. schools, may not be equipped with this equipment. There are some other ways to improve indoor air quality which may be more convenient and affordable. For example, evidence showed that negative air ions in the environment could help to improve air quality by reducing the PM_{2.5} and PM₁₀ concentrations in the air [Sawant VS., 2013]. PM_{2.5} refers to particulate matter with diameters of 2.5 microns or less, and PM₁₀ refers
30 to particulate matter with diameters of 10 microns or less.

Some reports showed that negative air ions attached themselves to particulate matter such as dust, cigarette smoke, mould spores, and other allergens. As a result, for

people exposed to negative air ions, symptoms of allergies to particulate matter tend to be alleviated. Generally, air enriched with negative air ions have multiple beneficial therapeutic effects, such as normalizing arterial pressure and blood rheology, supporting tissue oxygenation, easing stress conditions, and augmenting resistance to adverse factors. The concentration of negative air ions in the air is thus an important factor in evaluating air quality.

Artificial electrical negative ion generators have been widely used for enriching negative air ions in the air. However, the negative air ions are artificially produced and may be less beneficial to health than negative air ions produced in nature or by natural ways. In nature, negative air ions are created by lightning, ocean surfs, air flow friction, cosmic rays, waterfalls, and ultraviolet radiation. Negative air ions are also abundant in mountainous and forested areas and these negative air ions are usually released from trees and/or plants.

Others have described a device for generation of negative air ions from plants [Wu R, *et al.*, 2017]. The device generates voltage pulses having a very low frequency ranging from 0.5 Hz to 2 Hz, which requires complex circuit design with larger size of the device [Borgaonkar A, 2015]. In addition, the device requires a ground wire connection to earth and can be cumbersome to operate. Patent application PCT/CN2011/077325 and China utility model 203313745U describe a similar device that generates voltage pulses having a very low frequency. United States patent 9,736,993 B2 describes a device for release of negative air ions by a plant. The device comprises a housing for disposing a plant pot therein. One disadvantage with this device is that the plant pot has to be contained in the housing and is thus restricted by the size of the housing.

Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved apparatus and a device for generating negative air ions from plants.

Summary

According to a first aspect of the present invention, there is an apparatus for generating negative air ions from plants. The apparatus comprises: a planter comprising soil and one or more plants grown on the soil; and a portable device co-operable with the planter for generating negative air ions from the plants. The portable device comprises:

5 a pulse generator for generating voltage pulses having an internal operating frequency ranging from 18 kHz to 48 kHz; a pulse probe insertable into the soil for conducting the voltage pulses from the pulse generator to the soil; and a portable power source for powering the pulse generator, wherein the plant generates negative air ions in response to said conducting of the voltage pulses to the soil.

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According to a second aspect of the present invention, there is a portable device for use with plants to generate negative air ions from the plants. The portable device comprises: a pulse generator for generating voltage pulses having an internal operating frequency ranging from 18 kHz to 48 kHz; a pulse probe for coupling the

15 pulse generator to the plants, the pulse probe for conducting the voltage pulses to the plants; and a portable power source for powering the pulse generator, wherein the plants generate negative air ions in response to said conducting of the voltage pulses to the plants.

20 An advantage of the present invention is that the plants grown in the planter are stimulated by the high frequency voltage pulses generated by the portable device to generate more negative air ions, which is useful for removing particulate matter in the air. The portable device uses a portable power source to power the pulse generator, allowing the portable device to be more easily carried around and used with planters

25 at different locations. The apparatus is thus effective for eliminating air pollutants in the air, thereby cleaning and purifying the air and providing health benefits to people.

An apparatus and a device for generating negative air ions from plants according to the present invention are thus disclosed herein. Various features, aspects, and

30 advantages of the present invention will become more apparent from the following detailed description of the embodiments of the present invention, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is an illustration of an apparatus for generating negative air ions from plants, in accordance with various embodiments of the present invention.

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Figure 2A to Figure 2D are illustrations of planters being experimented in a growth chamber under indoor conditions, in accordance with various embodiments of the present invention.

10 Figure 2E is a table of results from the experiments of Figure 2A to Figure 2D, in accordance with various embodiments of the present invention.

Figure 3A to Figure 3C are illustrations of planters being experimented outdoors under pulsed electric field stimulation, in accordance with various embodiments of the present invention.

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Figure 3D to Figure 3F are results from the experiments of Figure 3A to Figure 3C, in accordance with various embodiments of the present invention.

20 Figure 4 is a table comparing the apparatus of Figure 1 with commercially available generators of negative air ions, in accordance with various embodiments of the present invention.

Figure 5A to Figure 5D are results from experiments on a portable power source of the apparatus of Figure 1, in accordance with various embodiments of the present invention.

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Figure 6A and Figure 6B are results from experiments on grounding connection for the apparatus of Figure 1, in accordance with various embodiments of the present invention.

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Figure 7A to Figure 7C are illustrations of taxonomies / phylogenetic trees of plant species, in accordance with various embodiments of the present invention.

Figure 8A is an illustration of selected plant species based on generation of negative air ions under indoor conditions, in accordance with various embodiments of the present invention.

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Figure 8B and Figure 8C are results from experiments on the selected plant species of Figure 8A on removal of particulate matter, in accordance with various embodiments of the present invention.

10 Figure 9A is an illustration of selected plant species based on generation of negative air ions under pulsed electric field stimulation, in accordance with various embodiments of the present invention.

Figure 9B shows results from experiments on the selected plant species of Figure 9A
15 on generation of negative air ions under pulsed electric field stimulation, in accordance with various embodiments of the present invention.

Figure 10 are results from an experiment comparing devices generating low frequency voltage pulses against the apparatus in accordance with various embodiments of the
20 present invention.

Figure 11A and Figure 11B show results from an experiment evaluating smoke removal by the apparatus in accordance with various embodiments of the present invention.

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Figure 12A and Figure 12B show results from an experiment evaluating negative air ion generation and particulate matter removal for long periods by the apparatus in accordance with various embodiments of the present invention.

30 Figure 13A to Figure 13D show various examples of the apparatus in accordance with various embodiments of the present invention.

Figure 14A and Figure 14B show various photos of the apparatus in accordance with various embodiments of the present invention.

Figure 15A and Figure 15B show various photos of the apparatus in accordance with various embodiments of the present invention.

Detailed Description

In the present invention, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith. The use of "/" in a figure or associated text is understood to mean "and/or" unless otherwise indicated. As used herein, the term "set" corresponds to or is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single element set, or a multiple element set), in accordance with known mathematical definitions. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range.

For purposes of brevity and clarity, descriptions of embodiments of the present invention are directed to an apparatus and a device for generating negative air ions from plants, in accordance with the drawings. While aspects of the present invention will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present invention to these embodiments. On the contrary, the present invention is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present invention as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present invention may be practiced without specific details, and/or with multiple

details arising from combinations of aspects of particular embodiments. In a number of instances, known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present invention.

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Representative or exemplary embodiments of the present invention describe an apparatus 100 for generating negative air ions from plants, with reference to Figure 1. As used herein, the apparatus 100 refers to a setup or a set of equipment operative for generating negative air ions. Particularly, the apparatus 100 comprises a portable
10 device 200 and a planter 300, e.g. a potted plant. The portable device 200 is an electronic device that is co-operable with a planter 300 for generating negative air ions from the planter 300. The planter 300 comprises a container 302 (e.g. pot, box, vase, or vessel), soil 304 disposed in the container 302, and one or more plants 306 grown on the soil 304. The plants 306 are of various species, namely terrestrial plant species
15 and hydrophytic / aquatic plant species. Furthermore, the plants 306 may be flowering plants or non-flowering plants, such as ferns. The plants 306 may be screened and selected based on various factors, such as their ability to generate or release negative air ions, as described below. As the apparatus 100 relies on the biology mechanisms of the plants 306 to generate negative air ions, the apparatus 100 may also be referred
20 to as a bio-generator.

The portable device 200 is configured for use with the plants 306 in the planter 300 for generating negative air ions from the plants 306. The portable device 200 is designed to be easily transported, i.e. carried or moved, by a person. The portable device 200
25 comprises a pulse generator 202 for generating voltage pulses from an internal operating frequency ranging from 18 kHz to 48 kHz. Additionally, the voltage pulses have an output pulse frequency that ranges from 0.02 kHz to 40 kHz. For example, the output pulse frequency may range from 0.02 kHz to 5 kHz, or from 5 kHz to 40 kHz, depending on the configuration / circuitry of the pulse generator 202 and/or on
30 the internal operating frequency. The pulse generator 202 is an electronic machine configured to generate rectangular pulses of predefined voltage levels, i.e. voltage pulses. The pulse generator 202 may thus be referred to as a voltage source. The pulse generator 202 generates or outputs voltage pulses with an output ranging from

1 kV to 40 kV. Preferably, the output ranges from 15 kV to 40 kV. In some experiments, the output is 20 kV in an open circuit at 50 μ A with an internal operating frequency of 48 kHz. In some experiments, the output is 30 kV in an open circuit at 80 μ A with an internal operating frequency ranging from 18 kHz to 35 kHz. In some embodiments, the output is 7 kV and an experiment was performed on the plant species *Dracena surculosa* to remove particulate matter, as described further below.

The portable device 200 further comprises a pulse probe 204 for coupling the pulse generator 202 to plants 306 in the planter 300. Specifically, the pulse probe 204 comprises a proximal end 206 connected to an output terminal of the pulse generator 202, and a distal end 208 insertable into the soil 304 in the planter 300. For example, the distal end 208 is inserted 10 cm deep into the soil 304. The pulse probe 204 is configured for conducting the voltage pulses from the pulse generator 202 to the plants 306. Specifically, the pulse probe 204 conducts the voltage pulses from the pulse generator 202 (whereto the proximal end 206 is connected) to the soil 304 (wherein the distal end 208 is inserted). The pulse probe 204 including its proximal end 206 and distal end 208 can be manufactured in various designs and shapes, such as to make it easier to operate by the user.

In some embodiments, the portable device 200 is separately located from the planter 300 and the pulse probe 206 extends across some distance and inserts into the soil 304. In some other embodiments, the portable device 200 is integrated with the planter 300, such as by a coupling mechanism with the container 302. The pulse probe 206 extends across a shorter distance and inserts into the soil 304.

The plants 306 generate and release negative air ions in response to said conducting of the voltage pulses to the plants 306. Although the plants 306 naturally release negative air ions, the generation of negative air ions is enhanced or improved because of the voltage pulses. Specifically, the pulse probe 204 generates a pulsed electric field in response to said conducting of the voltage pulses from the pulse generator 202 to the soil 304. The pulsed electric field stimulate the roots of the plants 306 grown inside the soil 304, thereby stimulating or enhancing generation of negative air ions from the plants 306. To reduce interference to the pulsed electric field, the planter 300

may be placed on an elevated base made of an electrical insulation material. The container 302 may also be made of a similar electrical insulation material.

The portable device 200 further comprises a portable power source 210 for powering the pulse generator 202. In some embodiments, the portable power source 210 comprises a set of batteries arranged in parallel. The batteries may be standard alkaline batteries or rechargeable batteries. In one embodiment, the power source 210 comprises a single 9-volt DC battery. In another embodiment, the power source 210 comprises six 9-volt DC batteries arranged in parallel. In some other embodiments, the power source 210 comprises one or more 12-volt DC batteries. In some other embodiments, the power source 210 is rechargeable, such as by plugging the portable device 200 to a power outlet or socket, to a Universal Serial Bus (USB) port of a computer, or to a power bank. It will be appreciated that suitable types of rechargeable batteries may be used for the power source 210, such as lithium-ion batteries. In some other embodiments, the power source 210 may include a power converter or transformer for converting AC power (from a power outlet / socket) to DC power.

Negative air ions are particles, e.g. atoms or molecules, in the air with one or more extra electrons. Some examples of negative air ions include, but are not limited to, oxygen ions (O_2^-), hydroxyl ions (OH^-), and carbonate ions (CO_4^-). The negative air ions generally combine with a set or cluster of water molecules, thereby forming $O_2^-(H_2O)_n$, $OH^-(H_2O)_n$, and $CO_4^-(H_2O)_n$ ions, respectively. Negative air ions such as oxygen ions can be released from the plants 306 by multiple pathways during photosynthesis and other enzyme reactions. In addition, there may be *in vitro* generation of oxygen ions by biochemical reactions. Notably, the presence of peptides with a hexa-repeat unit is correlated with the generation of oxygen ions.

The generation of negative air ions from the plants 306 is enhanced as a result of the portable device 200 producing the pulsed electric field. There is thus an increased amount and concentration of negative air ions in the air. The presence of more negative air ions in the air are particularly beneficial to human health and for air cleaning / purification. People tend to feel a sense of renewed vigour or well-being in an environment with a high concentration of negative air ions. Negative air ions are

credited for beneficial therapeutic effects, improvements in mood and physical health, productivity, and overall well-being, such as stabilized catecholamine regulation and circadian rhythm, normalizing arterial pressure and blood rheology, supporting tissue oxygenation, easing stress conditions, and augmenting resistance to adverse factors.

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The negative air ions also attach themselves, by magnetic attraction, to airborne particles or particulate matter, such as pollutants, dust, cigarette smoke, mould spores, pet dander, pollen, viruses, bacteria, and other allergens, to form larger particles. The newly-formed larger particles are too heavy to remain in the air and drops from the air.

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This may also be referred to as precipitation of particulate matter. The precipitation or removal of particulate matter from the air reduces the concentration of particulate matter in the air and improves air quality. The air is thus cleaned and/or purified by the negative air ions. As there is lower particulate matter concentration in the air, there is lower risk of people breathing or inhaling particulate matter into their lungs, which tend to cause problems such as allergic symptoms or reactions.

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Particulate matter in the air is the collective of all solid and liquid particles present in the air, many of which may be hazardous to people. Particulate matter can be divided into two broad groups – (i) $PM_{2.5}$ for particles with dimensions of 2.5 microns or less; and (ii) PM_{10} for particles with dimensions between 2.5 microns and 10 microns. Particulate matter may be more narrowly divided into four narrow groups – (i) PM_1 for particles with dimensions of 1 micron or less; (ii) $PM_{2.5}$ for particles with dimensions between 1 micron and 2.5 microns; (iii) PM_4 for particles with dimensions between 2.5 microns and 4 microns; and (iv) PM_{10} for particles with dimensions between 4 microns and 10 microns. The dimensions of particles or particle size may be defined in terms of their aerodynamic diameters, as will be readily understood by the skilled person.

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Air quality may be represented by various indices, such as the Pollutant Standards Index (PSI) and Air Quality Index (AQI). In some countries, the air quality is more specifically represented by concentrations of $PM_{2.5}$ and/or PM_{10} particles in the air. $PM_{2.5}$ particles can be particularly detrimental to health because these fine particles are so small and light, they tend to remain longer in the air than heavier particles, increasing the risk of people inhaling them. Due to their small sizes, $PM_{2.5}$ particles

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are able to bypass the nose and throat, penetrating deeper into the lungs and some particles may even enter the cardiovascular system. Inhalation of PM_{2.5} particles may trigger or worsen chronic diseases such as asthma, heart attack, bronchitis, and other respiratory problems. In some extreme cases, premature may eventually result from heart and lung disease.

For example, Singapore provides a near real-time indicator of the current air quality in terms of the 1-hour PM_{2.5} concentration, which is the average concentration of PM_{2.5} particles in the air over the past 1 hour. Singapore also provides other air quality indicators, such as in terms of the 24-hour PM_{2.5} concentration and 24-hour PM₁₀ concentration. The 1-hour PM_{2.5} concentration is defined in various bands and descriptors, which helps people to better interpret the readings and plan their activities, particularly since Singapore is at risk of haze. During a haze period, the main air pollutants are PM_{2.5} particles as they can harm the heart and lungs, especially in people who already have chronic heart or lung diseases. The 1-hour PM_{2.5} concentration is defined in four bands – Band I, Band II, Band III, and Band IV. In Band I, the 1-hour PM_{2.5} concentration is normal (55 µg/m³ or less) and is described as healthy. In Band II, the 1-hour PM_{2.5} concentration is elevated (56 µg/m³ to 150 µg/m³) and is described as unhealthy. In Band III, the 1-hour PM_{2.5} concentration is high (151 µg/m³ to 250 µg/m³) and is described as dangerous. In Band IV, the 1-hour PM_{2.5} concentration is very high (more than 250 µg/m³) and is described as hazardous.

Various experiments were done to assess the ability of the apparatus 100, including the portable device 200 and planter 300, to generate negative air ions from the planter 300, specifically from the plants 306 grown therein. In these experiments, the concentrations of negative air ions, PM_{2.5} particles, and PM₁₀ particles were measured.

In one experiment, the concentrations of negative air ions naturally generated by plants 306 in a planter 300 were measured for planters 300 with and without plants 306, as well as with and without stimulation by the pulsed electric field generated by the portable device 200. As shown in Figure 2A to Figure 2D, each planter 300 was placed in a sealed transparent growth chamber 400 with dimensions of 80 cm on each side. The soil 304 and plants 306 were subjected to indoor conditions and the

measurements were performed indoors under fluorescent lighting, specifically two fluorescent light tubes of 40 W each. An air ion counter 500, such as the DLY-4G(232) Air Ion Counter from Kilter Electronic Institute Co., Ltd, was used to measure or detect the concentration of negative air ions within the growth chamber 400. The air ion counter 500 was placed 5 cm away from the planter 300. The measurements lasted for 2 hours and the average value over the 2 hours was calculated as the average concentration of negative air ions generated by each planter 300.

The results of the experiment are shown in Table 1 in Figure 2E. Specifically, a planter 300 with soil 304 but without plants 306, being under indoor conditions without pulsed electric field stimulation, results in the lowest concentration of negative air ions – 55 NAIs/cm³. A planter 300 with soil 304 and plants 306, being under indoor conditions without pulsed electric field stimulation, results in a concentration of 120 NAIs/cm³. A planter 300 with soil 304 but without plants 306, being under pulsed electric field stimulation from the portable device 200, results in a concentration of 253 NAIs/cm³. A planter 300 with soil 304 and plants 306, being under pulsed electric field stimulation from the portable device 200, results in the highest concentration of negative air ions – 80 million NAIs/cm³. Evidently, the apparatus 100 significantly increases the amount of negative air ions generated by the planter 300 because of the portable device 200 co-operating with the planter 300 and stimulating the generation of negative air ions.

In another experiment, the apparatus 100 was placed outdoors, specifically in a greenhouse in open space and with natural light and temperature conditions. The planter 300 was subjected to pulsed electric field stimulation and the concentrations of negative air ions were then measured with an air ion counter 500. As the concentrations are expected to be significantly higher under pulsed electric field stimulation than under indoor conditions, this experiment provided a better evaluation of the ability of the planter 300, specifically the plants 306 grown therein, to generate negative air ions. The concentrations were measured at three different distances – 5 cm, 50 cm, and 100 cm – away from the air ion counter 500 as shown in Figure 3A to Figure 3C. For each distance, 60 measurement readings were taken over a duration of 60 seconds. The minimum, maximum, and average values for concentration of negative air ions were determined from these 60 measurement readings.

The results of the experiment are shown in Figure 3D to Figure 3F for the three distances – 5 cm, 50 cm, and 100 cm – respectively. The highest concentration of negative air ions was detected at the 5 cm distance for most species of plants 306 grown in the planter 300. Specifically, at the 5 cm distance as shown in Figure 3D, the concentration of negative air ions ranges from 4.67 to 158.67 million NAIs/cm³ depending on the species of plants 306, with an average of 82.03 million NAIs/cm³. At the 50 cm distance as shown in Figure 3E, the concentration of negative air ions ranges from 0 to 3.12 million NAIs/cm³ with an average of 1.27 million NAIs/cm³. At the 100 cm distance as shown in Figure 3F, the concentration of negative air ions ranges from 0 to 0.86 million NAIs/cm³ with an average of 0.38 million NAIs/cm³. Evidently, the detectable negative air ions generated from the planter 300 under pulsed electric field stimulation were significantly reduced with increasing distance away from the planter 300.

An experiment was performed to compare the apparatus 100 to other commercially available electrical generators based on the amount of negative air ions generated. Three electrical generators commercially available in the market were selected – (i) LightAir Ion Generator Style; (ii) Medical Ion Mini; and (iii) Sharp Ion Generator IG-GC2E. For each electrical generator, the maximum concentration of negative air ions was obtained from the manufacturer's product specification, the concentration being measured at 0-1 cm distance from the electrical generator. The maximum concentration of negative air ions generated by the apparatus 100 was also measured at 0-1 cm distance from the planter 300. The measurements are shown in Table 2 in Figure 4. Specifically, the Sharp Ion Generator IG-GC2E results in the lowest maximum concentration of negative air ions released – 0.075 million NAIs/cm³. The remaining two electrical generators – LightAir Ion Generator Style and Medical Ion Mini – resulted in higher maximum concentrations of negative air ions released – 19 million NAIs/cm³ and 8.5 million NAIs/cm³ respectively. The apparatus 100 resulted in the highest maximum concentration of negative air ions released – more than 100 million NAIs/cm³. Evidently, the apparatus 100 is commercially viable as it is able to generate a significantly higher amount of negative air ions as compared to these commercially available electrical generators.

Another experiment was performed to assess the apparatus' ability of the generated negative air ions to remove particulate matter in the air. In this experiment, the apparatus 100 was placed in the growth chamber 400 and particulate matter was artificially created. High concentrations of PM_{2.5} and PM₁₀ particles were created by burning an incense stick 2 minutes in the growth chamber 400. After the incense stick is burnt, the PM_{2.5} and PM₁₀ concentrations were around 500 µg/m³ and 1300 µg/m³, respectively. An electric fan was then turned on to facilitate air circulation inside the growth chamber 400. A particle counter, such as the Aerocet 831 Aerosol Mass Monitor from Met One Instruments, was used to measure or detect the concentrations of PM_{2.5} and PM₁₀ within the growth chamber 400. The PM_{2.5} and PM₁₀ concentrations were measured within the growth chamber 400 for three scenarios – (i) empty growth chamber 400; (ii) growth chamber 400 with the planter 300 without pulsed electric field stimulation; and (iii) growth chamber 400 with the planter 300 under pulsed electric field stimulation. For this experiment, the species of the plants 306 grown in the planter 300 is *Nautilocalyx lynchii*. The results of the experiment are shown in Figure 5A to Figure 5D for different types of portable power sources 210 used for powering the pulse generator 202 to generate the pulsed electric field.

Referring to Figure 5A and Figure 5B, the portable power source 210 comprises a single 9-volt DC battery to generate the pulsed electric field. There were insignificant reductions in the PM_{2.5} and PM₁₀ concentrations in the growth chamber 400 with the planter 300 without pulsed electric field stimulation. In contrast, the PM_{2.5} concentration was reduced from around 500 µg/m³ to less than 50 µg/m³ after 20 minutes, and was further reduced to almost zero after 20 minutes. Similarly, the PM₁₀ concentration was reduced from around 1300 µg/m³ to less than 100 µg/m³ after 15 minutes, and was further reduced to almost zero after 25 minutes.

Referring to Figure 5C and Figure 5D, the portable power source 210 comprises six 9-volt DC batteries arranged in parallel to generate the pulsed electric field. There were insignificant reductions in PM_{2.5} and PM₁₀ concentrations in the growth chamber 400 with the planter 300 without pulsed electric field stimulation. In contrast, the PM_{2.5} concentration was reduced from around 500 µg/m³ to less than 50 µg/m³ after 6

minutes, and was further reduced to almost zero after 10 minutes. Similarly, the PM₁₀ concentration was reduced from around 1300 µg/m³ to less than 100 µg/m³ after 10 minutes, and was further reduced to almost zero after 15 minutes.

5 Some studies have shown that the voltage levels of the voltage pulses generated by the pulse generator 202 affects the intensity of the pulsed electric field and thereby affects the generation of negative air ions from the planter 300 under pulsed electric field stimulation. For example, pulsed electric field stimulation by voltage pulses at 20 kV resulted in more negative air ions released than for pulsed electric field stimulation
10 by voltage pulses at 15 kV or lower. The change in voltage levels is not dependent on the type of power source used, which is one of the objectives in the experiment with reference to Figure 5A to Figure 5D. In this experiment, different portable power sources 210 were used to assess the ability of the planter 300 to reduce PM_{2.5} and PM₁₀ concentrations under pulsed electric field stimulation. The results show that the
15 portable power source 210 with multiple batteries arranged in parallel accelerates reductions of PM_{2.5} and PM₁₀ concentrations as compared to a portable power source 210 with a single battery. This experiment thus showed that the generation of negative air ions using the apparatus 100 could be improved by using different variations of the portable power source 210.

20 Pulsed electric field stimulation has been used in various fields, including food preservation, food processing, and water treatment. In all these applications, grounding to the earth has been regarded as a regular and necessary step. Grounding to the earth requires a physical connection to the earth, or to a structure that is
25 physically connected to the earth. An experiment was performed to assess how grounding to the earth affects the PM_{2.5} and PM₁₀ removal. The apparatus 100 is placed in the growth chamber 400 with the planter 300 under pulsed electric field stimulation. For this experiment, the species of the plants 306 grown in the planter 300 is *Nautilocalyx lynchii* as an example. Particulate matter was artificially created in the
30 growth chamber 400, and the initial PM_{2.5} and PM₁₀ concentrations were 400 µg/m³ and 700 µg/m³, respectively. The experiment was performed on the apparatus 100 first without a grounding connection to the earth and secondly with the addition of an independent grounding connection between the portable device 200 and the earth.

The results of the experiment are shown in Figure 6A and Figure 6B. The reductions in the PM_{2.5} and PM₁₀ concentrations in the growth chamber 400 were similar regardless of whether there was a grounding connection to the earth. Thus, the apparatus 100 can still effectively remove particulate matter even without a conventional grounding connection between the portable device 200 and the earth. The omission of the grounding connection allows the portable device 200 to be designed as more portable and convenient to be carried around by a person or user.

In some embodiments with reference to Figure 1, the portable device 200 comprises a switch 212 for activating and deactivating the pulse generator 202. Accordingly, the switch 212 turns on and off the flow of electrical power from the portable power source 210 to the pulse generator 202. The portable device 200 may further comprise a wireless communication module connected to the switch 212 and communicable with an electronic device. This electronic device may be a mobile device, e.g. mobile phone, or a remote control for remotely controlling the portable device 200. Specifically, the electronic device is configured for remotely activating and deactivating the pulse generator 202 by switching on and off the portable power source 210. The wireless communication module may communicate with the electronic device by known wireless communication protocols, such as Bluetooth, Wi-Fi, NFC, infrared, RF, etc.

In some embodiments, the portable device 200 further comprises a set of particulate matter sensors for detecting particulate matter concentration, such as the PM_{2.5} and PM₁₀ concentrations. There may be one or multiple particulate matter sensors to improve the accuracy of the detected particulate matter concentration. Each particulate matter sensor may be a particle counter, such as the Aerocet 831 Aerosol Mass Monitor. The portable device 200 may be automatically controlled, e.g. by controlling the switch 212 to activate / deactivate the pulse generator 202, based on feedback from the particulate matter sensors. For example, in a current state, the switch 212 is turned off and the pulse generator 202 is deactivated. If the particulate matter sensors detect that the particulate matter concentration is above a predefined level, the switch 212 automatically turns on and activates the pulse generator 202. This predefined level or threshold may be a PM_{2.5} concentration of 50 µg/m³. The

predefined level may be defined based on the Bands used in Singapore. For example, when the PM_{2.5} concentration crosses from Band I (healthy) to Band II (unhealthy), i.e. the PM_{2.5} concentration crosses above 55 µg/m³, the pulse generator 202 is automatically activated to facilitate generation of negative air ions to thereby remove the particulate matter.

In some embodiments, the portable device 200 further comprises a set of proximity sensors for detecting presence of objects, including people, proximate to the portable device 200. There may be one or multiple proximity sensors disposed around the portable device 200 to detect objects from all directions. Each proximity sensor may include an ultrasonic or infrared controller module. It will be appreciated that motion detectors may similarly be used to detect presence of people based on their movements nearby the portable device 200. The portable device 200 may be automatically controlled, e.g. by controlling the switch 212 to activate / deactivate the pulse generator 202, based on feedback from the proximity sensors. For example, in a current state, the switch 212 is turned on and the pulse generator 202 is activated. If the proximity sensors detect that an object, e.g. a person, is approaching and is within a predefined distance from the proximity sensors, the switch 212 automatically turns off and deactivates the pulse generator 202. This predefined distance may be defined as 30 cm or a distance which prevents people from reaching out and touching the plants 306.

When the pulse generator 202 is activated, voltage pulses are conducted from the pulse generator 202 to the soil 304. The voltage pulses stimulate the roots of the plants 306 grown in the soil, causing the plants 306 to release negative air ions. If a person is very close to or touches the plants 306, there may be a strong flow of negative air ions from the leaf points/tips of the plants 306 to the body, i.e. an electrical discharge from the plants 306 to the body, and the person may feel an electrical shock. In mild cases, the electric shock may not cause damage to the person, but it is still an undesirable experience nonetheless. To mitigate the risk of electric shock, the apparatus 100 may be installed in a place where people may not reach. Alternatively, a mechanical protective system may be installed around the apparatus 100 to prevent people from touching it. The implementation of the proximity sensors in the apparatus

100 provides a safety feature in that people can be kept safe from electric shocks and potential electrical injuries if they touch the plants 306, because the pulse generator 202 is automatically deactivated when people gets within the predefined distance from the proximity sensors. Alternatively or additionally, the portable device 200 may
5 include a voltage sensing precautionary circuit that automatically deactivates the pulse generator 202 in response to detecting an object or human touching the plants 306, e.g. the plant leaves wherefrom the negative air ions are released.

As stated above, the plants 306 grown in the planter 300 may be of various species
10 that are screened and selected based on various factors. In one experiment, 120 species of vascular plants were identified for screening and selection, in order to determine which plant species have the best ability to generate negative air ions in the growth chamber 400 without pulsed electric field stimulation. Each planter 300 with plants 306 of one of the plant species was then used in the apparatus 100 to assess
15 the abilities of the respective plant species. The average concentration of negative air ions released from the planter 300 were measured with an air ion counter 500.

Figure 7A illustrates the taxonomy / phylogenetic tree of the 120 plant species. Specifically, the 120 plant species consist of 113 seed plants and 7 ferns. The 113
20 seed plants consist of 109 flowering plants and 4 other seed plants. The 109 flowering plants consist of 54 eudicots, 51 monocots, and 4 other flowering plants. The 7 ferns consist of 1 rough horsetail and 6 other ferns. Figure 7B illustrates the taxonomy / phylogenetic tree of the 54 eudicots and Figure 7C illustrates the taxonomy / phylogenetic tree of the 51 monocots. The specific plant species names are stated in
25 Figure 7A to Figure 7C, along with the average amount of negative air ions generated by each of the 120 plant species.

The results of the experiment showed that different plants 306 release different amounts of negative air ions. Some plants 306 release very low amounts of negative
30 air ions (less than 10 NAIs/cm³) while others release much higher amounts. Notably, flowering plants generally produced higher concentrations of negative air ions than non-flowering plants. The average among the 120 plant species is 120 NAIs/cm³. With reference to Figure 7A, seed plants excluding the eudicots and monocots release

negative air ions ranging from 6 NAIs/cm³ (*Magnolia figo* and *Zamia pumila*) to 211 NAIs/cm³ (*Araucaria angustifolia* or Paraná pine) with an average of 97 NAIs/cm³. Ferns release negative air ions ranging from 11 NAIs/cm³ (*Diplazium esculentum*) to 188 NAIs/cm³ (*Equisetum hyemale* or rough horsetail) with an average of 106 NAIs/cm³. With reference to Figure 7B, eudicots release negative air ions ranging from zero (*Euphorbia trigona*) or 1 NAI/cm³ (*Lespedeza bicolor*) to 297 NAIs/cm³ (*Codiaeum variegatum* or garden croton) with an average of 140 NAIs/cm³. With reference to Figure 7C, monocots release negative air ions ranging from 1 NAI/cm³ (*Sansevieria cylindrica*) to 293 NAIs/cm³ (*Dracaena reflexa*) with a higher average of 132 NAIs/cm³.

Based on these results, 8 plant species were selected with the average concentration of more than 250 NAIs/cm³, as shown in Figure 8A. The 8 plant species are from either the eudicot or the monocot plant species. The 8 plant species are *Andrographis paniculata* (common andrographis herb; 271 NAIs/cm³), *Ilex aquifolium* (common holly herb; 251 NAIs/cm³), *Ficus lyrata* (fiddle-leaf fig; 278 NAIs/cm³), *Euphorbia flanaganii* (medusa head; 282 NAIs/cm³), *Codiaeum variegatum* (garden croton; 297 NAIs/cm³), *Dracaena surculosa* (289 NAIs/cm³), *Dracaena reflexa* (pleomele; 293 NAIs/cm³), and *Bromelia agavifolia* (262 NAIs/cm³). The 8 plant species show better release of negative air ions than other plant species and may be a good choice for indoor decoration, such as for ornamental plants.

In another experiment, the selected 8 plant species are assessed on their abilities of these plant species to remove particulate matter and reduce PM_{2.5} and PM₁₀ concentrations in the growth chamber 400 without pulsed electric field stimulation. Particulate matter was artificially created in the growth chamber 400, and the PM_{2.5} and PM₁₀ concentrations were measured with a particle counter. Particulate matter was also created in an empty growth chamber 400, i.e. without any plants 306, to serve as a reference for comparison. The initial PM_{2.5} and PM₁₀ concentrations were 500 µg/m³ and 900 µg/m³, respectively.

The results of the experiment are shown in Figure 8B and Figure 8C. In the empty growth chamber 400 without any plants 306, the PM_{2.5} and PM₁₀ concentrations were naturally reduced to 418.6 µg/m³ and 466.8 µg/m³, respectively after 2 hours. The

PM_{2.5} and PM₁₀ concentrations were further reduced to 225.7 µg/m³ and 301.3 µg/m³, respectively after another 2 hours. After the 8 different plants 306 are individually introduced into the growth chamber 400 to naturally release negative air ions without pulsed electric stimulation, the PM_{2.5} concentration was reduced to 41.1 µg/m³ and 130.5 µg/m³ after 4 hours, as shown in Figure 8B. Similarly, the PM₁₀ concentration was reduced to 43.9 µg/m³ and 150.5 µg/m³ after 4 hours, as shown in Figure 8C. Evidently, the plants 306 contribute significantly to removal of particulate matter. Based on these results, it was found that 2 plant species – *Dracaena surculosa* and *Ficus lyrata* – showed significantly better ability in reducing PM_{2.5} and PM₁₀ concentrations.

In another experiment, the same 120 plant species were assessed in an outdoor environment. The apparatus 100 was placed in a greenhouse with natural light and temperature conditions. Each planter 300 with plants 306 of one of the plant species was then used in the apparatus 100 to assess the abilities of the respective plant species. The planter 300 was subjected to pulsed electric field stimulation by the portable device 200, and the average concentration of negative air ions were measured with an air ion counter 500 at three different distances – 5 cm, 50 cm, and 100 cm – away from the air ion counter 500.

The results of the experiment are shown in Figure 3D to Figure 3F, including the minimum, maximum, and average values for concentration of negative air ions. Based on these results, 10 plant species were selected as shown in Figure 9A. Each of the selected 10 plant species has met these criteria related to concentration of negative air ions – (i) more than 100 million NAIs/cm³ at the 5 cm distance; (ii) more than 2 million NAIs/cm³ at the 50 cm distance; and (iii) more than 0.5 million NAIs/cm³ at the 100 cm distance.

Table 3 in Figure 9B shows the average measured concentrations of negative air ions for each of the 10 plant species at each of the three distances. The 10 plant species are from either the eudicot or the monocot plant species. The 10 plant species are *Acalypha hispida*, *Codiaeum variegatum*, *Dendrolobium umbellatum*, *Desmodium chinensis*, *Epipremnum aureum* (devil's ivy), *Euphorbia flanaganii*, *Ficus elastica*

(rubber fig), *Hibiscus mutabilis*, *Philodendron bipinnatifidum*, and *Sansevieria trifasciata* (viper's bowstring hemp).

Notably, the plant species that is common in the 8 plant species selected under indoor conditions without pulsed electric field stimulation and the 10 plant species selected under outdoor conditions with pulsed electric field stimulation is the *Codiaeum variegatum* or garden croton. This plant species may be most effective for use with the apparatus 100 for generating negative air ions and for removal of particulate matter under pulsed electric field stimulation.

Plant architecture and/or leaf morphology of the plants 306 may affect the ability of the plants 306 to generate negative air ions. Dense leaves may also weaken the plants' ability to release negative air ions. Specifically, although more leaves may generate more negative air ions, there is limited space among the leaves for the generated negative air ions to be released into the air. In some embodiments, the plants 306 may optionally be pruned or trimmed to remove crowded leaves and increase space among the leaves, thereby facilitating release of negative air ions generated by the plants 306.

The experiments showed that different plant species generated different amounts of negative air ions. Therefore, the generation of negative air ions can be improved by growing certain plant species. These plant species with better abilities to generate negative air ions may be further improved by breeding selection and genetic modification, and may be used for future selection to develop plant varieties with better abilities to generate negative air ions.

Other devices for generation of negative air ions from plants, such as the devices described in [Wu R, et al., 2017] and PCT/CN2011/077325, generate voltage pulses having a very low output frequency ranging from 0.5 Hz to 2 Hz. In contrast, the portable device 200 of the present invention generates voltage pulses having a high frequency. An experiment was performed to evaluate how the frequency affected the generation of negative air ions. The results of the experiment are shown in Table 4 in Figure 10.

With reference to Figure 10, the device of [Wu R, et al., 2017] was used on the plant species *Zephyranthes carinata* with a plant size of 42 cm in width and 41 cm in height. The device generated voltage pulses having an output of 20 kV and an output frequency ranging from 0.5 Hz to 2 Hz. The measured concentration of negative air ions ranged from 3.24 to 3.95 million NAIs/cm³ [Wu R, et al., 2017]. The device of PCT/CN2011/077325 was used on the spider plant. The device generated voltage pulses having an output of 20 kV and an output frequency of 0.5 Hz. The measured concentration of negative air ions was around 0.04 million NAIs/cm³ [PCT/CN2011/077325].

Comparing with the present invention, the portable device 200 was used on the plant species *Dracaena surculosa* with a plant size of 35 cm in width and 35 cm in height. The measured concentration of negative air ions ranged from 63.29 to 64.92 million NAIs/cm³. The portable device 200 was also used on the same plant species *Dracaena surculosa* but with a plant size of 46 cm in width and 60 cm in height. When the plant size increased to 46cm in width and 60cm in height, the measured concentration of negative air ions ranged from 75.89 to 84.91 million NAIs/cm³. Therefore, based on the experiment results as shown in Table 4, the portable device 200 generated the highest concentrations of negative air ions, thus achieving a higher efficiency than existing devices that generate very low output frequency voltage pulses.

An experiment was performed to evaluate the effectiveness of the apparatus 100 to remove smoke. The smoke was generated by burning tissue papers in the growth chamber 400. The apparatus 100 was used with the plant species *Dracaena surculosa*. Figure 11A shows photos of the growth chamber 400 at different times from 0 to 5 minutes after the apparatus 100 was activated. The experiment included a control whereby there is no apparatus 100 in the growth chamber 400 to remove smoke. The smoke was visible from 0 to 1 minute after the apparatus 100 was activated. After 2 minutes of treatment by the apparatus 100, the growth chamber 400 was clear and nearly no smoke was visible. On the contrary, the control without the apparatus 100 showed no significant difference. The results of this experiment showed the high efficiency of the apparatus 100 in smoke removal. Figure 11B shows the reduction of PM_{2.5} concentration over 15 minutes using the apparatus 100 with the plant species

Dracaena surculosa. Specifically, the device 200 generated voltage pulses with an output of 7 kV. This experiment shows that the apparatus 100 works at output voltages at the lower region of the range 1 kV to 40 kV.

5 An experiment was performed to examine the effect of pulsed electric field stimulation for long periods (8 hours per day) on plant growth, generation of negative air ions from the plants, as well as removal of particulate matter using the apparatus 100. In the experiment, the plant species *Sansevieria trifasciata* was treated by the apparatus 100 for 9 months for 8 hours per day. The apparatus 100 had a 12 V DC input and
10 generated voltage pulses having a 20 kV output. Similar plants from the same plant species growing under normal growth conditions served as a control (CK). The concentrations of negative air ions during treatment by the apparatus 100 and in the control were measured per month by the air ion counters 500. As shown in Figure 12A, the results of this experiment showed that during the 9-month period, the concentration
15 of negative air ions ranged from 100 to 110 million NAIs/cm³ for the control and ranged from 101 to 115 million NAIs/cm³ for the treatment by the apparatus 100. Thus, through a long period of treatment by the apparatus 100, the concentration of negative air ions was insignificantly different the control, suggesting that the plants 306 can be subjected to long periods of treatment or stimulation by the portable device 200 without
20 damaging the plants 306 and reducing the generation of negative air ions.

The experiment further evaluated the removal of particulate matter for both the control (CK) and the treatment by the apparatus 100. The PM_{2.5} concentrations were measured every month for a 10-minute duration. As shown in Figure 12B, the results
25 of this experiment showed that the PM_{2.5} concentration reduced from more than 1000 µg/m³ to less than 50 µg/m³ within the 10-minute duration for both the control and the treatment by the apparatus 100. The results showed similar effectiveness between the control and the treatment by the apparatus 100 in particulate matter removal. Furthermore, no visible damage was observed during the 9-month period under the
30 treatment by the apparatus 100, suggesting that the plants 306 can be subjected to long periods of treatment or stimulation by the portable device 200 without damaging the plants, and reducing the generation of negative air ions, and compromising particulate matter removal.

Various embodiments of the present invention describe an apparatus 100 for generating negative air ions from plants 306, as well as a portable device 200 for use with plants 306 to generate negative air ions from the plants 306. Various experiments
5 have been performed to assess the effectiveness of the apparatus 100 and portable device 200 to generate negative air ions and to remove particulate matter. In the apparatus 100, the portable device 200 is co-operable with the planter 300 comprising the plants 306 to subject the plants 306 to pulsed electric field stimulation. Under the pulsed field stimulation, the plants 306 generate more negative air ions – in the order
10 of 100 million NAIs/cm³ – which is generally higher than many commercially available electrical generators. Thus, the apparatus 100 is more effective generating negative air ions and consequently more effective in removing particulate matter in the air. The efficiency of the apparatus 100 is also improved by optimizing the portable power source 210, e.g. by using a set of batteries arranged in parallel. As the pulse generator
15 202 is powered by the portable power source 210, the portable device 200 is more easily carried around and can be used with planters 300 at different locations. The apparatus 100 may be used in various locations, such as home/office space, public parks, lawns, green walls, and green buildings.

Figure 13A to Figure 13D show various examples of the apparatus 100 that is suitable for use in a home / office space. The device 200 may be integrated with a data connector 214, such as a USB or micro USB port, and may be powered or charged by an external USB charger. The device 200 has the pulse probe 206 with a distal end 208 that is insertable into the soil 304 of the planter 300 for conducting the voltage
25 pulses to the soil 304. The distal end 208 may be formed of unshielded metal material. The device 200 may include an illumination element 216, such as a light-emitting diode (LED) to provide visual indications to the user. For example, these visual indications relate to the power status of the device 200. Various plant species may be used as the plants 306 in the planter 300. Some non-limiting examples include *Sansevieria trifasciata* (Figure 13B), *Dracaena surculosa* (Figure 13C), and *Dracaena sanderiana*
30 (Figure 13D). The container 302 of the planter 300 may be made from insulating materials by an additive manufacturing process, such as using a 3D printer.

Figure 14A and Figure 14B show additional photos of the apparatus 100. The apparatus 100 includes the portable device 200 having a rechargeable power source 210. The rechargeable power source 210 may include rechargeable batteries such as lithium-ion batteries. The portable device 200 may be plugged or connected to a power outlet or socket 102 via a charging plug 104 and a charging cable 106 for charging the power source 210. The charging plug 104 and charging cable 106 may be from regular USB charging devices of mobile devices or phones. The charging cable 106 may alternatively be plugged into a power bank or a computer USB port for charging the power source 110. After the power source 210 is recharged and/or has sufficient power, the device 200 can be unplugged and the device 200 can be used with the planter 300 to stimulate generation of negative air ions. The device 200 may also be used with the planter 300 while remaining connected or plugged to the power outlet 102.

Figure 15A and Figure 15B show additional photos of the apparatus 100 and the device 200 with different designs.

In the foregoing detailed description, embodiments of the present invention in relation to an apparatus and a device for generating negative air ions from plants are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present invention, but merely to illustrate non-limiting examples of the present invention. The present invention serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present invention are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this invention that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present invention. Therefore, the scope of the invention as well as the scope of the following claims is not limited to embodiments described herein.

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Claims

1. An apparatus for generating negative air ions from plants, the apparatus comprising:

5 a planter comprising soil and one or more plants grown on the soil; and
a portable device co-operable with the planter for generating negative air ions from the plants, the portable device comprising:

a pulse generator for generating voltage pulses from an
internal operating frequency of the pulse generator ranging from
10 18 kHz to 48 kHz, the voltage pulses having an output pulse
frequency ranging from 5 kHz to 40 kHz and an output voltage
ranging from 1 kV to 40 kV;

a pulse probe insertable into the soil for conducting the voltage
pulses from the pulse generator to the soil; and

15 a portable power source for powering the pulse generator,
wherein a pulsed electric field is generated in response to said
conducting of the voltage pulses to the soil, the pulsed electric field for
stimulating generation of negative air ions from the plants.

20 2. The apparatus according to claim 1, wherein the portable device further
comprises a set of particulate matter sensors for detecting particulate matter
concentration.

3. The apparatus according to claim 2, wherein the pulse generator is
25 automatically activated if the particulate matter concentration is above a predefined
level.

4. The apparatus according to any one of claims 1 to 3, wherein the portable
device further comprises a set of proximity sensors for detecting presence of objects
30 proximate to the portable device.

5. The apparatus according to claim 4, wherein the pulse generator is automatically deactivated if an object is detected within a predefined distance from the proximity sensors.

5 6. The apparatus according to any one of claims 1 to 5, further comprising an electronic device for remotely controlling the portable device.

7. The apparatus according to claim 6, wherein the portable device comprises a wireless communication module communicable with the electronic device.

10

8. The apparatus according to any one of claims 1 to 7, wherein the portable power source comprises a set of batteries arranged in parallel.

9. The apparatus according to any one of claims 1 to 8, wherein the plants belong
15 to one or more plant species in the group consisting of: *Andrographis paniculata*, *Ilex aquifolium*, *Ficus lyrata*, *Euphorbia flanaganii*, *Codiaeum variegatum*, *Dracaena surculosa*, *Dracaena reflexa*, and *Bromelia agavifolia*.

10. The apparatus according to any one of claims 1 to 8, wherein the plants belong
20 to one or more plant species in the group consisting of: *Acalypha hispida*, *Codiaeum variegatum*, *Dendrolobium umbellatum*, *Desmodium chinensis*, *Epipremnum aureum*, *Euphorbia flanaganii*, *Ficus elastica*, *Hibiscus mutabilis*, *Philodendron bipinnatifidum*, and *Sansevieria trifasciata*.

25 11. A portable device for use with plants to generate negative air ions from the plants, the portable device comprising:

a pulse generator for generating voltage pulses from an internal
operating frequency of the pulse generator ranging from 18 kHz to 48 kHz, the
voltage pulses having an output pulse frequency ranging from 5 kHz to 40 kHz
30 and an output voltage ranging from 1 kV to 40 kV;

a pulse probe for coupling the pulse generator to the plants, the pulse
probe for conducting the voltage pulses to the plants; and

a portable power source for powering the pulse generator,

wherein a pulsed electric field is generated in response to said conducting of the voltage pulses to the plants, the pulsed electric field for stimulating generation of negative air ions from the plants.

5 12. The portable device according to claim 11, further comprising a set of particulate matter sensors for detecting particulate matter concentration.

13. The portable device according to claim 12, wherein the pulse generator is automatically activated if the particulate matter concentration is above a predefined
10 level.

14. The portable device according to any one of claims 11 to 13, further comprising a set of proximity sensors for detecting presence of objects proximate to the portable device.
15

15. The portable device according to claim 14, wherein the pulse generator is automatically deactivated if an object is detected within a predefined distance from the proximity sensors.

20 16. The portable device according to any one of claims 11 to 15, further comprising a switch for activating and deactivating the pulse generator.

17. The portable device according to claim 16, further comprising a wireless communication module connected to the switch and communicable with an electronic
25 device, the electronic device configured for remotely activating and deactivating the pulse generator.

18. The portable device according to any one of claims 11 to 17, wherein the portable power source comprises a set of batteries arranged in parallel.
30

19. A method of using a portable device with plants to generate negative air ions from the plants, the method comprising:

coupling a pulse probe of the portable device to the plants, the pulse probe for coupling the plants to a pulse generator of the portable device and for conducting voltage pulses from the pulse generator to the plants;

powering the pulse generator with a portable power source; and

5 activating the pulse generator for generating voltage pulses from an internal operating frequency of the pulse generator ranging from 18 kHz to 48 kHz, the voltage pulses having an output pulse frequency ranging from 5 kHz to 40 kHz and an output voltage ranging from 1 kV to 40 kV;

10 generating a pulsed electric field in response to said conducting of the voltage pulses to the plants; and

stimulating generation of negative air ions from the plants using the pulsed electric field.