METHOD AND APPARATUS FOR TREATING SOIL

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a method and apparatus for treating soil and, more particularly, to a method and apparatus for treating soil with electromagnetic radiation to kill bacteria and other organisms present in the soil.

BACKGROUND OF THE INVENTION

It is generally known to treat soil to remove living organisms in the soil which may interfere with the growth of certain types of vegetation. For example, U.S. Patent No. 4,995,190 to Royer, issued February 26, 1991, discloses treating soil by fumigating the soil with a gas to sterilize the soil. The apparatus disclosed in the Royer patent utilizes alkyl halide gases, such as methyl bromide, to treat the soil. One of the problems associated with treating soil with gas fumigants is that many of the fumigants used for this purpose, such as methyl bromide, are extremely toxic. Furthermore, in addition to being toxic, methyl bromide is a hydrocarbon and thus its use is harmful to the atmosphere.

It is also known in the industry to use chemicals to treat soil. However, many of the chemicals used for this purpose are extremely toxic. Therefore, the use of such chemicals to treat soil is highly restricted under the environmental laws due to the potentially harmful effects to humans and animals resulting from their use.

Attempts have also been made to treat soil using electromagnetic radiation. Approximately twenty years ago, attempts were made to sterilize soil using electromagnetic radiation by passing an irradiating horn over the soil. The horn emitted electromagnetic radiation into the soil. However, these attempts proved unsuccessful. One of the problems associated with this approach was that the radiation was not sufficiently concentrated into the soil to efficiently treat the soil because not all of the radiation that impinged on the soil was absorbed by the soil because of reflection.

Therefore, the radiation was not capable of being sufficiently concentrated into the soil to adequately sterilize the soil.

However, treating soil with electromagnetic radiation may have many benefits over treating soil with chemicals or fumigants. If the electromagnetic radiation is applied to the soil in such a manner that it can be concentrated into the soil while preventing or minimizing, within acceptable industry standards, exposure of humans to the electromagnetic radiation, treating soil with electromagnetic radiation could be a viable, and possibly superior, alternative to other types of soil treatment processes, such as chemicals and fumigants.

Accordingly, a need exists for a method and apparatus for treating soil with electromagnetic radiation which provide sufficient exposure of the soil to the radiation to sterilize the soil while preventing exposure of humans to the radiation.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for treating soil with electromagnetic radiation. The apparatus of the present invention comprises an electromagnetic radiation applicator which the soil travels through as it is being irradiated, a conveyer system that conveys the soil through the applicator as it is being irradiated, an input port through which the soil is fed into the applicator, and an output port through which the soil exits the applicator after the soil has been sterilized. An electromagnetic radiation source is coupled to the apparatus of the present invention for supplying radiation to the applicator. The electromagnetic radiation source generates electromagnetic radiation which is directed into the applicator and concentrated into the soil being conveyed through the applicator.

In accordance with the preferred embodiment of the present invention, the input and output ports are each coupled to soil conduit assemblies through which the soil entering and exiting the applicator passes. Each of the soil conduit assemblies

functions as a waveguide beyond cutoff to prevent radiation from escaping from the applicator through the soil conduit assemblies. The electromagnetic radiation source preferably is coupled to the applicator at a plurality of locations along the applicator via a plurality of waveguides so that the soil will be uniformly exposed to the radiation as it passes through the applicator. The electromagnetic radiation generated by the electromagnetic radiation source propagates along the waveguides into the applicator. A seal which is transparent to the frequency of the electromagnetic radiation is provided at the interface between each waveguide and the applicator to allow the radiation to pass through the seals into the applicator while preventing soil from exiting the applicator and entering the waveguides.

Preferably, the applicator is water cooled via a cooling jacket which surrounds the applicator. Water or some other type of coolant is provided to the jacket from a reservoir which is exterior to the applicator. In accordance with the preferred embodiment of the present invention, the conveying system comprises a drive motor located at one or both ends of the applicator and one or more screws mechanically coupled at one end to the motor(s) and at the other end to either another motor or a bearing. The applicator is longitudinal in shape and the screw is axially aligned with the longitudinal axis of the applicator. As the motor turns the screw, soil which has been fed into the applicator is propagated by the screw through the applicator.

Other aspects, features and advantages of the present invention will become apparent from the following description, drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of the apparatus of the present invention in accordance with the preferred embodiment.

Fig. 2 is a top view of the soil conduit assembly connected to the input port of the applicator shown in Fig. 1.

Fig. 3 is a block diagram of the apparatus of the present invention shown in Fig. 1 in accordance with the preferred embodiment having an electromagnetic radiating source coupled thereto via a plurality of circulators and waveguides.

Fig. 4 is a block diagram of the apparatus of the present invention according to another preferred embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 is block diagram of the apparatus 1 of the present invention in accordance with the preferred embodiment. In accordance with the preferred embodiment, the apparatus 1 comprises an applicator 2 having an input port 3 for receiving soil to be sterilized and an output port 4 through which the soil exits the applicator 2 after being sterilized. A conveying system comprising a first drive motor 6, a screw 8 having an end coupled to the motor 6, and a second drive motor 9 which is coupled to the other end of screw 8. However, it will be apparent to those skilled in the art that only one drive motor 6 may be needed for turning the screw 8. In this case, motor 9 will be replaced by a bearing (not shown) that receives the end of the screw opposite motor 6 which allows the end of the screw to rotate as the screw is turned by the motor 6.

Preferably, the shaft of the screw 8 is comprised of three portions, namely, a first portion 18, which has screw blades attached thereto, a second portion 21, which has no screw blades attached to it, and a third portion 23, which also has screw blades attached thereto. The portions of the shaft 18 and 23 are comprised of metal so that they are conductive and are cylindrical in shape and hollow. The second portion of the shaft 21 preferably is comprised of a ceramic material and is perforated to allow gases, such as steam, to migrate into the second portion 21, which is also cylindrical in shape and hollow. The third portion 23 preferably is also perforated to allow gases to migrate into the third portion 23.

Preferably, the first portion 18 of the shaft is blocked at location 15 where the first metal portion 18 is interfaced to the second ceramic portion 21. The manner in which the metal portion 18 is bonded with the ceramic portion 21 will not be discussed in detail herein since the manner in which this can be accomplished is well known to those skilled in the art. Preferably, water under pressure supplied by a water pump (not shown) is allowed to flow through the hollow interior of the first portion 18 of the screw 8 from the open end of the screw attached to the motor 6 toward the blocked end of the first portion 18. Perforations formed in the first portion 18 allow water to enter the central cavity of the applicator 2. By regulating the amount of water allowed to flow into the central cavity, the relative permittivity of the soil can be altered, if so desired. The water flowing into the applicator 2 preferably is regulated using a sensing device (not shown) which senses when more or less water is needed and provides a signal to the water pump to turn the pump on and off. Altering the relative permittivity of the soil can alter the electromagnetic radiation modes set up in the applicator 2, thereby altering the effect of the radiation on the soil, as discussed below in detail.

As the soil being propagated through the applicator 2 is irradiated, steam and/or other gases may be released from the soil. These gases will migrate through the pores in the second and/or third portions 21 and 23 of the screw 8. The gases will then pass out of the applicator 2 through an opening (not shown) in the end of the third portion 23 attached to the applicator 2. The ends of the first and third portions of the screw 8 that are attached to the applicator 2 preferably will be electromagnetically sealed by choke devices (not shown) to prevent electromagnetic radiation from escaping into the environment through these openings. Choke devices that are suitable for this purpose are well known in the art and, therefore, will not be further discussed herein in the interest of brevity.

A first flange 12 is attached to the input port 3 of the applicator 2 and a second flange 14 is attached to the output port 4 of the applicator 2. Soil conduit assemblies 16

and 17 are attached to the first and second flanges 12 and 14, respectively. Preferably, conduit assemblies of different sizes can be attached to the flanges 12 and 14 to control the consistency, as well as other characteristics, of the soil entering the input port 3. The soil entering the applicator 2 will have a relative permittivity that depends, at least in part, on the moisture content of the soil. The soil conduit assembly 16 preferably is comprised of chutes 19, which are indicated by the dashed lines in assembly 16. The size of these chutes 19 controls the consistency or granularity of the soil ultimately entering the applicator 2. When the soil is relatively dry, a conduit assembly 16 having very wide chutes can be attached to the applicator 2 because the relative permittivity is relatively low. On the other hand, if the soil has a high moisture content, the relative permittivity will be higher and a conduit assembly 16 having relatively narrow chutes should be attached to the applicator 2.

Soil received into the applicator 2 through the input port 3 is propagated through the applicator 2 via the screw 8 to the output port 4 of the applicator 2. As the soil is propagated through the applicator 2, the soil is exposed to electromagnetic radiation injected into the applicator 2 from an electromagnetic radiation source (not shown). The electromagnetic radiation heats the soil to a very high temperature so that any bacteria or other types of living organisms are killed, thus sterilizing the soil. In order to prevent the electromagnetic radiation from leaking out of the applicator 2, the soil conduit assemblies 16 and 17 are designed to function at waveguides beyond cutoff so that any electromagnetic radiation that is coupled into the soil conduit assemblies 16 and 17 is attenuated. The soil conduit assemblies 16 and 17 are discussed in more detail below with respect to Fig. 2.

Fig. 2 is a top view of the soil conduit assembly 16 connected to the input port of the applicator shown in Fig. 1 in accordance with the preferred embodiment of the present invention. As stated above, the conduit assembly 16 is comprised of a plurality of adjacent, interconnected chutes 19. Each of the chutes 19 is comprised of four

adjoining walls which define a cell. The dimensions of the cells are chosen such that the conduit assembly 16 functions as a waveguide beyond cutoff, as discussed in more detail below. By designing the assembly 16 to function as a waveguide beyond cutoff, substantially all of the radiation coupled into the assembly 16 from the applicator 2 is attenuated, thereby preventing exposure of the environment to the radiation.

The dimensions of the chutes 19 are chosen to be small enough so that the waveguides, when filled with soil of varying moisture content and, therefore, varying relative permittivities, will be beyond the cutoff frequency of the radiation and will dramatically attenuate the electromagnetic energy. The applicator 2 preferably is entirely electromagnetically sealed, except that the conduit assemblies 16 and 17 are open to allow soil to enter the chutes 19. In order to calculate the dimensions of the chutes 19, the relative permittivity of the soil, ε, must be taken into consideration. As stated above, the relative permittivity of the soil, ε, depends at least in part on the moisture content of the soil. In accordance with the present invention, it has been determined through experimentation that ε will vary from approximately 3 when the soil is very dry to approximately 30 when the soil is completely saturated.

For a chute which is a square waveguide, a = b = w, where a, b and w are the side dimensions of the chute, the cut-off frequency for the two fundamental modes of propagation, TE_{10} and TE_{01} is given by $f_c = \frac{c}{2w\sqrt{\varepsilon}}$, where $c = 1 \times 10^{10}$ cm/sec, and ε = permittivity. Therefore, to determine the "cut-off dimension" for f = 2450 mhz, the above equation is rewritten in terms of w as $w = \frac{c}{2f\sqrt{\varepsilon}}$. Thus, as the relative permittivity increases, the dimension w must decrease in proportion to the $\sqrt{\varepsilon}$. For $\varepsilon = 3$, $\therefore w = \frac{c}{2f\sqrt{3}} = \frac{3x10^{10}}{2x2450x10^{6}\sqrt{3}} = 3.53$ cm = 1.39"

For $\varepsilon = 30$, the width of each of the sides of one of the chutes 19 is calculated as follows:

$$w = \frac{c}{2f\sqrt{30}} = \frac{3x10^{10}}{2x2450x10^{6}\sqrt{30}} = 1.117 \text{ cm} = 0.439"$$

Of course, in order to allow for tolerances, variances, etc., each of these dimensions should be reduced by approximately 10% for "wet" soil, i.e., $\varepsilon = 30$ and, therefore, the cell opening should be no more than 0.4 inches. However, for "dry" soil, i.e., $\varepsilon = 3$, the cell opening can be as large as 1 ¼". However, it will be understood by those skilled in the art that the present invention is not limited to this range for ε.

Thus, in accordance with the preferred embodiment of the present invention, in order for the soil conduit assemblies 16 and 17 to function as waveguides beyond cutoff at the preferred frequency of irradiation, the dimensions of the chutes 19 will vary between approximately 0.4" x 0.4" when the soil is saturated and 1.250" x 1.250" when the soil is dry. However, it will be apparent to those skilled in the art that the present invention is not limited to these dimensions or to the soil conduit assembly design shown in Figs. 1 and 2. This is merely the preferred manner for preventing radiation from escaping from the applicator 2. Other designs can be used for this purpose as well. Furthermore, it will be understood by those skilled in the art that other means can be used for introducing the soil into the applicator 2 which do not require the use of the soil conduit assemblies 16 and 17 shown in Figs. 1 and 2. Also, those skilled in the art will understand that, if the power of the radiation used to irradiate the soil in the applicator is relatively low, the need to use waveguides beyond cutoff for the soil conduit assemblies may be obviated.

Preferably, the soil conduit assemblies 16 and 17 are designed to be field-attached by the operator. The soil conduit assemblies 16 and 17 can be attached to the flanges 12 and 14 by any desired fastening device, such as, for example, nuts and bolts. This feature of the present invention allows the operator to determine which soil conduit assembly should be attached to the input and output ports upon determining the granularity and moisture content of the soil. Soil conduit assembly 17 preferably is identical in design to soil conduit assembly 16. However, since the relative permittivity of the soil exiting the applicator 2 will likely be different from the relative permittivity of the soil entering the applicator, the dimensions of the chutes of soil conduit assembly 17 may be different in size from those of soil conduit assembly 16. It will be

understood by those skilled in the art the manner in which the soil conduit assemblies 16 and 17 should be constructed to achieve the desired results.

Fig. 3 is a block diagram of the applicator 2 of the present invention having an electromagnetic radiation device 31 coupled thereto for irradiating the soil. The drive motors 6 and 9, the screw 8 and the soil conduit assemblies 16 and 17 are not shown in Fig. 3 for ease of illustration. In accordance with the preferred embodiment of the present invention, the electromagnetic radiation device 31 is a magnetron device which generates a 30 kilowatt signal at a frequency of 2450 MHz. The magnetron device is connected to a power supply (not shown) which supplies power to the magnetron device to enable it to generate the electromagnetic radiation. Preferably, the radiation is coupled into the applicator 2 at several locations along the applicator 2 so that multiple modes are set up within the applicator 2. However, it will be understood by those skilled in the art that the present invention is not limited with respect to the manner in which the radiation is coupled into the applicator 2. The radiation should be coupled into the applicator 2 in such a manner that sterilization of the soil is maximized and accomplished efficiently. It will also be understood by those skilled in the art that the present invention is not limited to any particular frequency or frequency range of radiation. Also, it may be desirable to use frequency sweeping, as will be understood by those skilled in the art. The frequency of the radiation is chosen to effect complete and efficient irradiation of the soil. Therefore, the present invention is not limited to any particular electromagnetic radiation device.

The radiation source 31 is electromagnetically coupled into a circulator 32 via a first waveguide 33. Circulators of the type implemented with the present invention are well known in the art and are designed to circulate the electromagnetic energy that enters them until substantially all of the radiation has been output to the desired location while preventing the radiation from being coupled back into the waveguide feeding the circulator 32 due to impedance mismatches, as will be understood by those skilled in the art. The radiation entering the circulator 32 is coupled from circulator 32 into circulator 35 via waveguide 34. Any radiation in circulator 32 that does not enter waveguide 34 is circulated to waveguide 36. Most of the radiation that reaches waveguide 26 is coupled into the applicator 2. Any radiation that is not output to the applicator 2 via waveguide 36 is coupled into the heat sink 45 via waveguide 37.

Radiation coupled into circulator 35 is distributed to different points about the applicator 2 via waveguides 38, 41 and 43. Any radiation not coupled into applicator 2 via waveguide 38 will be circulated to waveguide 41. Any radiation not coupled into applicator 2 via waveguide 41 will be circulated to waveguide 43. Any radiation not coupled into applicator 2 via waveguide 43 will be circulated to waveguide 34 and coupled back into circulator 32. This radiation will then be handled by circulator 32 in the above-discussed manner.

Figure 4a is a block diagram of another preferred form of the present invention, Fig. 4b showing an end detail of an applicator 102 and connecting wave guides 138, 141, 143, 146. An electromagnetic radiation device 131 is coupled to the applicator 102 for irradiating the soil. The various components of the embodiment depicted in Fig. 4 are preferably substantially similar to corresponding components described herein with reference to Fig. 3, the principal difference relating to the waveguide connection arrangement between components. The radiation source 131 is electromagnetically coupled into a circulator 132 via a first waveguide 133. The radiation entering the circulator 132 is coupled from circulator 132 into second circulator 135 via waveguide 134. Any radiation in circulator 132 that does not enter waveguide 134 is circulated to waveguides 138, 141. Most of the radiation that reaches waveguides 138, 141 is in turn coupled into the applicator 102. Radiation coupled into circulator 135 is distributed to the applicator 102 via waveguides 143, 146. Any radiation that is not output to the applicator 102 is coupled into the heat sink 145 via waveguide 137. As shown in Fig. 4b, the waveguides 138, 141, 143, 146 are preferably distributed about the applicator 102.

Preferably, a glass seal (not shown) is provided at the interface between each of the waveguides 38, 41, 43 and 46 and the applicator 2 to prevent soil being propagated through the applicator 2 from entering the waveguides. The glass seals are transparent to the frequency of the radiation being supplied to the applicator 2. It will be apparent to those skilled in the art that any type of seal that is suitable for this purpose can be used with the present invention for this purpose.

As stated above, other types of conveying systems can be used for conveying the soil through the applicator 2. However, the screw 8 is preferred over other types of conveying devices, such as, for example, endless belts. One benefit obtained from

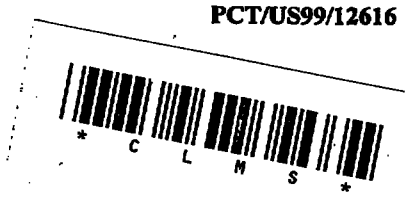
using the screw 8 is that the screw 8 is comprised of a conductive material and functions as a spiral waveguide, thereby assisting in setting up modes within the applicator 2. Another advantage obtained by using a screw 8 as the conveying device is that the screw 8 increases the exposure time of the soil over that which would be obtained using an endless belt due to the fact that the screw 8 propagates the soil in a spiral or helical fashion through the applicator 2, as opposed to in a straight line.

The applicator 2 is comprised throughout of a conductive material, preferably metal. The dimensions of the applicator 2 preferably are large relative to the wavelength of the radiation used to irradiate the soil. By making the dimensions of the applicator 2 large with respect to the wavelength of the radiation, the applicator 2 is forced to function as a multi-mode applicator, as will be understood by those skilled in the art. The shape and electric relative permittivity of the load also affect the modes existing in the applicator 2. Normally, evanescent modes are generated due to scattering fields created by the load boundary conditions. However, since, in accordance with the preferred embodiment of the present invention, the soil is evenly distributed within the applicator cavity, it is not anticipated that evanescent modes will occur. However, since the moisture content of the soil may vary, thus causing the electric relative permittivity to vary, the nature of the modes set up in the applicator 2 will also vary.

In accordance with the preferred embodiment of the present invention, the electric relative permittivity of the soil propagating through the applicator 2 is controlled by controlling the amount of moisture in the soil. As stated above with respect to Fig. 2, preferably water is supplied to soil propagating through the applicator 2 through the hollow interior of the first portion 18 of the screw 8. The amount of water supplied to the soil may be determined by the operator. However, it will be apparent to those skilled in the art that the moisture content of the soil being fed into the applicator through the input port can be measured automatically by using an appropriate sensor device and the amount of water supplied to the soil within the applicator 2 can be controlled automatically to achieve the desired moisture content for the soil. It will be understood by those skilled in the art that a variety of sensor devices are suitable for this purpose.

Preferably, the applicator 2 of the present invention can be attached to a plow or tractor so that soil can be treated as a field is being plowed. In this case, some means will be provided for delivering soil into the input port 3 of the applicator 2. It will be apparent to those skilled in the art that a variety of means can be utilized for this purpose. Once the soil has been treated, the soil exiting the applicator 2 through the output port 4 is delivered via some means to the ground. It will also be apparent to those skilled in the art that a variety of means can be utilized for this purpose.

It will be apparent to those skilled in the art that, although the present invention has been described with respect to the preferred embodiment, the present invention is not limited to this embodiment. It will be understood by those skilled in the art that modifications may be made to the embodiments discussed above without deviating from the spirit and scope of the invention.



WHAT IS CLAIMED IS:

1. An apparatus for treating soil comprising:

an applicator comprised of a conductive material, the applicator having an input port for receiving soil to be treated into the applicator and an output port for discharging soil from the applicator once it has been treated;

a conveyer comprised by the applicator, the conveyer conveying soil to be treated through the applicator from the input port of the applicator to the output port of the applicator, wherein radiation supplied to the applicator irradiates the soil as it is propagated through the applicator to thereby treat the soil.

2. The apparatus of claim 1, wherein the irradiated soil is completely sterilized by the radiation.

3. The apparatus of claim 1, wherein the conveyer comprises a screw, the screw being coupled on one end to a motor, the screw being rotationally coupled on the other end to the applicator, wherein the motor turns the screw thereby causing the soil to be propagated through the applicator.

4. The apparatus of claim 3, wherein the applicator is longitudinal in shape and having a longitudinal axis, the screw turning about an axis which is parallel to the longitudinal axis of the applicator, the applicator having dimensions which are large relative to the wavelength of the radiation supplied to the applicator such that a plurality of radiation modes exist in the applicator, wherein the radiation is supplied to the applicator at a plurality of locations about the applicator.

5. The apparatus of claim 4, wherein the radiation has a frequency of approximately 2450 megahertz.



6. The apparatus of claim 4, wherein the applicator receives water from an external water source, the water source being controllable to control the amount of water being received into the applicator, thereby controlling the moisture content of the soil being propagated through the applicator.

7. The apparatus of claim 6, wherein the input port is coupled to a first soil conduit assembly through which soil passes to enter the applicator, the first soil conduit assembly comprising a plurality of chutes, each of the chutes having predetermined dimensions, wherein the dimensions of the chutes are chosen such that the first soil conduit assembly functions as a waveguide beyond cutoff whereby any of the radiation propagating into the first soil conduit assembly from the applicator is attenuated by the first soil conduit assembly.

8. The apparatus of claim 7, wherein the output port is coupled to the second soil conduit assembly through which soil passes to enter the applicator, the second soil conduit assembly coupled to the output port comprising a plurality of chutes, each of the chutes of the second soil conduit assembly having predetermined dimensions that are chosen such that the second soil conduit assembly functions as a waveguide beyond cutoff whereby any of the radiation propagating into the second soil conduit assembly from the applicator is attenuated by the second soil conduit assembly.

9. A system for treating soil comprising:

an applicator comprised of a conductive material, the applicator having an input port for receiving soil to be treated into the applicator and an output port for discharging soil from the applicator once it has been treated;

a conveyer comprised by the applicator, the conveyer conveying soil to be treated through the applicator from the input port of the applicator to the output port of the applicator; and

an electromagnetic radiation source electromagnetically coupled to the applicator, the electromagnetic radiation source generating radiation to be supplied to the applicator, wherein radiation supplied to the applicator irradiates the soil as it is propagated through the applicator to thereby treat the soil.

10. The system of claim 9, wherein the irradiated soil is completely sterilized by the radiation.

11. The system of claim 9, wherein the conveyer comprises a screw, the screw being coupled on one end to a motor, the screw being rotationally coupled on the other end to the applicator, wherein the motor turns the screw thereby causing the soil to be propagated through the applicator.

12. The system of claim 11, wherein the applicator is longitudinal in shape and has a longitudinal axis, the screw turning about an axis which is parallel to the longitudinal axis of the applicator, the applicator having a length which is large relative to the wavelength of the radiation supplied to the applicator such that a plurality of radiation modes exist in the applicator, wherein the radiation is supplied to the applicator at a plurality of locations about the applicator.

13. The system of claim 12, wherein the radiation has a frequency of approximately 2450 megahertz.

14. The system of claim 12, wherein the applicator receives water from an external water source, the water source being controllable to control the amount of water being received into the applicator, thereby controlling the moisture content of the soil being propagated through the applicator.

15. The system of claim 12, wherein the input port is coupled to a first soil conduit assembly through which soil passes to enter the applicator, the first soil conduit assembly comprising a plurality of chutes, each of the chutes having predetermined dimensions, wherein the dimensions of the chutes are chosen such that the first soil conduit assembly functions as a waveguide beyond cutoff whereby any of the radiation propagating into the first soil conduit assembly from the applicator is attenuated by the first soil conduit assembly.

16. The system of claim 13, wherein the output port is coupled to a second soil conduit assembly through which soil passes to enter the applicator, the second soil conduit assembly coupled to the output port comprising a plurality of chutes, each of the chutes of the second soil conduit assembly having predetermined dimensions that are chosen such that the second soil conduit assembly functions as a waveguide beyond cutoff whereby any of the radiation propagating into the second soil conduit assembly from the applicator is attenuated by the second soil conduit assembly.

17. A method for treating soil comprising the steps of:

receiving soil to be treated in an applicator, the applicator being comprised of a conductive material, the soil being received through an input port of the applicator;

conveying the soil to be treated through the applicator from the input port of the applicator to an output port of the applicator;

irradiating the soil with electromagnetic radiation as the soil is propagated through the applicator to thereby treat the soil; and

discharging the soil from the applicator through the output port once it has been treated.

18. The method of claim 17, wherein the step of irradiating the soil, the soil is completely sterilized.

19. The method of claim 17, wherein the soil is conveyed by a screw, the screw being coupled on one end to a motor, the screw being rotationally coupled on the other end to the applicator, wherein the motor turns the screw thereby causing the soil to be propagated through the applicator.

20. The method of claim 19, wherein the applicator is longitudinal in shape and has a longitudinal axis, the screw turning about an axis which is parallel to the longitudinal axis of the applicator, the applicator having a length which is large relative to the wavelength of the radiation supplied to the applicator such that a plurality of radiation modes exist in the applicator, wherein, during the radiation step, the radiation is supplied to the applicator at a plurality of locations about the applicator.

21. The method of claim 20, wherein the radiation has a frequency of approximately 2450 megahertz.

22. The method of claim 17, further comprising the step of supplying water to the soil being propagated through the applicator, wherein the applicator receives water from an external water source, the water source being controllable to control the amount of

water being received into the applicator, thereby controlling the moisture content of the soil being propagated through the applicator.