

An organic waste treatment systemTechnical Field

The present invention relates to an organic waste treatment system and a method of
5 treating organic waste.

Background

For municipal solid waste, a significant and largely under-utilized fraction is the organic waste. Compared with landfill and incineration, diverting organic waste from municipal solid waste is more desirable for environmental stewardship, policy requirement, and
10 sustainable development. Currently, the primary treatment/management strategies to divert organic wastes from landfill and incineration are biological approaches, such as composting, and anaerobic digestion. These techniques can reduce the greenhouse gas emissions when compared to landfilling and generate valuable resources, such as fertilizer, methane gas, at the same time. However, the problems associated with
15 current technologies are that the organic waste and the associated packing materials must be separated prior to treatment. Further, the treatment processes are time consuming, are processes with high carbon footprints, achieve little volume reduction of the wastes, and release unpleasant process-related odours.

There is therefore a need for an improved organic waste treatment process.

20 Summary of the invention

The present invention seeks to address these problems, and/or provides an improved system for treating organic waste.

In general terms, the invention relates to a system for continuous conversion of organic waste in a fast, efficient and green manner. In particular, the system's energy
25 consumption is relatively low as the system is configured to use heat generated from one part of the system to heat other parts of the system where heat may be required. In this way, the amount of external heating required to run the system is reduced. Further, the system enables the organic waste to be converted into biochar, which is also free of any biohazards, making it a useful and environmentally friendly end
30 product. The method of the present invention is also a green method since the energy consumption is low and because it enables a reduction in organic waste volume. Further, as the system and method can be run on site where the organic waste is

produced, it would result in a reduction in logistic cost for transporting the organic waste to a waste treatment plant, as well as reduction in spread of odour from the organic waste.

According to a first aspect of the present invention, there is provided an organic waste treatment system comprising:

- an inlet for receiving organic waste;
- a crusher coupled to the inlet for reducing the size of the organic waste;
- a pre-treatment chamber for pre-treating the organic waste; and
- a carbonization chamber for treating the pre-treated organic waste to form biochar.

The organic waste may be any suitable organic waste for the purposes of the present invention.

According to a particular aspect, the pre-treatment chamber may comprise one or more units. In particular, the pre-treatment chamber may comprise two or more units. Even more in particular, the pre-treatment chamber may comprise two units. Accordingly, the pre-treatment chamber may comprise a heat exchanging unit and a pre-heating unit.

The system may further comprise a heat source for heating gas comprised in the carbonization chamber and the pre-heating unit. The heat source may be any suitable heat source.

According to a particular aspect, the system may further comprise a heat exchanger between the pre-treatment chamber and the collection chamber.

The carbonization chamber may comprise an inlet for receiving an additive. The additive may be any suitable additive. For example, the additive may be an inert gas. In particular, the additive may be nitrogen gas, argon, helium gas or a combination thereof.

The system may further comprise a collection chamber for collecting the formed biochar.

According to a particular aspect, the system may further comprise a separator at the inlet, wherein the separator is configured to separate metal from the organic waste received through the inlet.

5 The system may further comprise a conveyor configured to move organic waste received from the inlet through the pre-treatment chamber and the carbonization chamber.

The system may also comprise a temperature controller configured to measure temperatures of the pre-treatment chamber and the carbonization chamber and adjust speed of the conveyor.

10 According to a particular aspect, the crusher may comprise a seal to prevent any odour from the organic waste from escaping into the atmosphere. In this way, the odour from the organic waste is contained within the system.

15 According to a particular aspect, the system may further comprise a waste liquid collection chamber in fluid communication with the crusher for collecting waste liquid from the crusher. The waste liquid collection chamber may further comprise a liquid filtration system for treating the waste liquid collected before being discharged. In this way, the system discharges clean liquid following treatment of the organic waste.

20 According to a particular aspect, the system may further comprise a flue gas treatment system in fluid communication with the collection chamber for treating flue gas from the carbonization chamber. In use, the carbonization chamber may emit flue gas which may therefore be treated before being discharged into the atmosphere.

According to a second aspect, there is provided a method of treating organic waste using the system described above.

25 According to a third aspect, there is provided a method for treating organic waste, the method comprising:

- providing organic waste to a crusher through an inlet;
- crushing the organic waste to reduce size of the organic waste;
- heating the organic waste to increase temperature of the organic waste;
- and

- torrefying the organic waste to form biochar.

The organic waste may be any suitable organic waste for the purposes of the present invention.

- 5 The torrefying may comprise torrefying the organic waste in the presence of an inert gas. For example, the inert gas may be nitrogen gas, argon, helium gas, or a combination thereof.

- 10 The method may further comprise separating metal from the organic waste received through the inlet prior to the crushing. Any suitable method for separating the metal may be used.

According to a particular aspect, the method may further comprise treating waste liquid obtained from the crushing in a liquid filtration system.

According to a particular aspect, the method may further comprise treating flue gas produced during the torrefying.

15 Brief Description of the Drawings

In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments, the description being with reference to the accompanying illustrative drawings. In the drawings:

- 20 Figure 1 shows a schematic representation of the organic waste treatment system according to one embodiment of the present invention;

Figure 2 shows a schematic representation of a sealing system of the organic waste treatment system according to one embodiment of the present invention;

- 25 Figure 3 shows a schematic representation of a waste water filtration system according to one embodiment of the present invention;

Figures 4A and 4B show schematic representations of a flue gas treatment system according to one embodiment of the present invention; and

Figure 5 shows the carbon conversion fraction at different temperatures.

Detailed Description

As explained above, there is a need for an improved system and method for treating organic waste.

5 The present invention relates to a system for treating organic waste. In particular, the system for treating organic waste enables organic waste to be converted into energy-rich biochar which may then be used as a source of energy in other applications. The system also enables a rapid and green treatment of the organic waste since the system utilises less energy as compared to traditional organic waste treatment systems.

10 With the system of the present invention, the treatment of the organic waste can be carried out on site, thus saving time and cost in transporting the organic waste to another location to carry out the treatment. The system also has features which allows for plastic material and packaging accompanying the waste to be treated. This cuts down the time required for further separation systems to be used prior to the treatment of the waste. Further, the system is such that all the output from the system is
15 environmentally friendly and utilisation of energy in using the system is minimised, making the system a green system with a low carbon footprint.

The present invention also relates to a method for treating organic waste. The method is a green method with a low carbon footprint as the by-products from the method may be recycled in the method, thereby resulting in lower energy consumption.

20 Generally, the system and the method of the present invention provide a continuous, rapid and green system and method which requires less carbon footprint, achieves a reduction of organic waste volume, and is easy to operate as compared to traditional processes of treating organic waste, while at the same time yielding a useful end product in the form of biochar.

25 According to a first aspect of the present invention, there is provided an organic waste treatment system comprising:

- an inlet for receiving organic waste;
- a crusher coupled to the inlet for reducing the size of the organic waste;
- a pre-treatment chamber for pre-treating the organic waste; and

- a carbonization chamber for treating the pre-treated organic waste to form biochar.

The organic waste may be any suitable organic waste for the purposes of the present invention. For example, the organic waste may comprise material such as food, animal and plant based material, degradable carbon such as paper, cardboard and timber, plastics and the like.

The crusher may be any suitable crusher capable of reducing the size of the organic waste. For example, the crusher may comprise a blade which is configured to cut the organic waste including plastic material into smaller pieces. The crusher is also configured to remove water from the organic waste fed into the system. This enables the crushed organic waste to have a high solid content. Since the crusher is configured to remove water from the organic waste, the overall efficiency of the system is improved as less energy will be required by the subsequent parts of the system.

The crusher may further comprise a seal to prevent any odour from the organic waste from escaping the system and into the atmosphere. In this way, the odour from the organic waste is contained within the system. Any suitable seal may be used for the purposes of the present invention which may be able to seal the system thereby preventing any emission from the system. In particular, the seal may be a rubber seal or a gasket.

The system may further comprise a separator at the inlet of the system, wherein the separator is configured to separate metal from the organic waste received through the inlet. In particular, the separator is placed before the crusher. In this way, the crusher is protected from the hard metal, thereby maintaining the condition of a blade part of the crusher.

The separator may be any suitable separator. According to a particular aspect, the separator may be a metal detector and an alarm. The alarm may sound if the metal detector detects a metal, thereby prompting the separation and removal of the metal detected. According to another particular aspect, the separator may be an electromagnet. In particular, the separator may comprise an electromagnetic metal detector and an alarm.

A waste liquid collection chamber in fluid communication with the crusher may also be provided. The waste liquid collection chamber may be for collecting waste liquid from the crusher during the crushing of the organic waste.

5 The waste liquid collection chamber may further comprise a liquid filtration system for treating the waste liquid collected before being discharged. In this way, the system discharges clean liquid following treatment of the organic waste. The liquid filtration system may be any filtration system suitable for treating waste liquid into clean liquid.

10 The pre-treatment chamber may be any chamber suitable for pre-treating the organic waste prior to treatment in the carbonization chamber. For example, the pre-treating may comprise heating the organic waste. The pre-treatment chamber comprised in the system of the present invention may comprise one or more units. In particular, the pre-treatment chamber may comprise two or more units. Even more in particular, the pre-treatment chamber may comprise two units. Accordingly, the pre-treatment chamber may comprise a heat exchanging unit and a pre-heating unit. The heat exchanging unit
15 may not comprise an external heat source. The pre-heating unit may comprise an external heat source for heating gas and organic waste contained in the pre-heating unit. The heat source may be any suitable heat source. For example, the heat source may be an electric heater, steam, microwave, gas burner, solar-powered panel and the like.

20 The carbonization chamber may be any chamber suitable for treating the pre-treated organic waste. For example, the treating may comprise carbonizing and/or torrefying the pre-treated organic waste. The carbonization chamber may comprise an inlet for receiving an additive. The additive may be any suitable additive for use in carbonizing and/or torrefying the pre-treated organic waste. For example, the additive may be an
25 inert gas. In particular, the inert gas may be nitrogen gas, argon, helium gas, or a combination thereof.

The carbonization chamber may comprise an external heat source for heating gas contained in the carbonization chamber. The heat source may be any suitable heat source. For example, the heat source may be an electric heater, steam, microwave,
30 gas burner, solar-powered panel and the like.

The system may further comprise a collection chamber for collecting the formed biochar. The collection chamber may be connected to the carbonization chamber and may be adjacent the pre-treatment chamber. The collection chamber may comprise a product levelling bar which is configured to distribute the biochar formed evenly within the collection chamber.

The system may comprise a conveyor configured to move organic waste received from the inlet through the pre-treatment chamber and the carbonization chamber. The organic waste which has been treated in the carbonization chamber and formed into biochar is then dropped into the collection chamber. The conveyor may be any suitable conveyor for transporting the organic waste from the inlet through to the collection chamber. For example, the conveyor may be, but not limited to, a moving belt or a plug-feed screw conveyor. According to a particular aspect, the conveyor may be part a moving filter belt and part a moving belt.

According to a particular aspect, the system may further comprise a heat exchanger between the pre-treatment chamber and the collection chamber. The heat exchanger may be any suitable heat exchanger. The heat exchanger may provide heat exchange between the biochar collected in the collection chamber and the gas comprised in the pre-treatment chamber. In particular, the heat exchanger enables heat to be exchanged between the biochar and the pre-treatment chamber such that the temperature of the pre-treatment chamber is increased or maintained at a pre-determined temperature.

The pre-treatment chamber and the carbonization chamber are maintained at suitable temperatures. Accordingly, in order to minimise heat loss, the system comprises heat insulation between the pre-treatment chamber and the carbonization chamber. In particular, there is provided insulation between: (i) the heat exchanging unit and the pre-heating unit; (ii) the pre-heating unit and the carbonization chamber; and/or (iii) the carbonization chamber and the collection chamber. The heat insulation may be provided by any suitable means. For example, the heat insulation may be by, but not limited to, ceramic, vermiculite, asbestos, perlite, calcium silicate bricks, rock wool, and the like.

The system may also comprise a temperature controller configured to measure temperatures of the pre-treatment chamber and the carbonization chamber and

accordingly adjust speed of the conveyor. In particular, the temperature controller is configured to adjust the speed of the conveyor to ensure that the organic waste undergoes sufficient temperature in each of the pre-treatment chamber and the carbonization chamber depending on the temperature of each of the chambers. The temperature controller may comprise an alarm to alert a user if the temperatures of the pre-treatment chamber and/or the carbonization chamber fall below a certain pre-determined temperature. The temperature controller may be further connected to the heat source to adjust the amount of heat being supplied to the pre-treatment chamber and the carbonization chamber.

According to a particular aspect, the system may further comprise a flue gas treatment system in fluid communication with the collection chamber for treating flue gas from the carbonization chamber. In use, the carbonization chamber may emit flue gas which may therefore be treated before being discharged into the atmosphere. In this way, the system of the present invention does not emit any harmful and/or odourful gas into the atmosphere, making the system an environmentally friendly system. The flue gas treatment system may be any suitable system for the purposes of the present invention.

Figure 1 shows an organic waste treatment system 100 according to one embodiment of the present invention. The system 100 comprises an inlet 102 into which the organic waste to be treated is fed. The inlet 102 is connected to a crusher 104. The crusher may be as described above. The crusher 104 may further comprise a crusher outlet sealing system 106, which may be as shown in Figure 2. There is also provided a metal detector and alarm 108 between the inlet 102 and the crusher 104. The metal detector and alarm ensure that any metal in the organic waste fed into the inlet 102 is separated from the rest of the organic waste. This is to ensure that the metal does not undergo any crushing by the crusher 104, thereby protecting the blade comprised in the crusher 104. The system 100 further comprises a first conveyor 110 to transport the crushed organic waste from the crusher 104 to the other parts of the system 100. In particular, the first conveyor 110 may be a moving filter belt. As a result of the crusher 104 crushing the organic waste, liquid may be squeezed out of the organic waste. This liquid may flow through the first conveyor 110 and into a waste liquid collection chamber 112, while the crushed organic waste is retained on the first conveyor 110.

The waste liquid collection chamber 112 may further comprise a liquid filtration system 114. An example of the liquid filtration system 114 is as shown in Figure 3.

The crushed organic waste is then transported by way of the first conveyor 110 to a pre-treatment chamber 116. The organic waste may undergo pre-treatment such as heating before it is carbonized. The pre-treatment chamber 116 comprises a heat exchanging unit 118 and a pre-heating unit 120. The organic waste is first heated in the heat exchanging unit 118 and then in the other pre-heating unit 120. In particular, the first conveyor 110 is joined to a second conveyor 124 and the organic waste is transferred from the first conveyor 110 to the second conveyor 124. The second conveyor 124 may be any suitable conveyor such as a moving belt with 3-sided blocks and front bottom blade and back top block. According to the embodiment, the second conveyor 124 may begin at the start of the heat exchanging unit 118. The conveyor 124 therefore transports the organic waste through the heat exchanging unit 118 and the pre-heating unit 120.

There is provided a heat insulation panel 122 between the heat exchanging unit 118 and the pre-heating unit 120. The heat insulation panel 122 may be made of any suitable heat insulating material. In particular, the heat insulation panel 122 ensures that the heat is retained within the heat exchanging unit 118 and the pre-heating unit 120.

The system 100 also comprises a carbonization chamber 126 for treating the pre-treated organic waste to form biochar. The carbonization chamber 126 may be any suitable chamber in which torrefaction or carbonization of the organic waste may be carried out. The carbonization chamber 126 may comprise an inlet 130 for receiving additives such as inert gases.

There is provided a heat insulation panel 128 between the pre-heating unit 120 and the carbonization chamber 126. The heat insulation panel 128 may be made of any suitable heat insulating material. In particular, the heat insulation panel 128 ensures that the heat is retained within the pre-heating unit 120 and the carbonization chamber 126.

An external heat source 132 and 134 may be provided to heat up the gas within the pre-heating unit 120 and the carbonization chamber 126, respectively. The external

heat source 132 and 134 may be connected to a temperature controller and alarm (not shown). In particular, when the temperature controller detects that the temperature in the pre-heating unit 120 and the carbonization chamber 126 falls below a pre-determined temperature, the temperature controller will sound an alarm. The temperature controller may further cause the heat source to increase the amount of heat being supplied to the pre-heating unit 120 and the carbonization chamber 126. Alternatively, the alarm may prompt a user of the system 100 to cause the heat source to start to supply more heat to the pre-heating unit 120 and the carbonization chamber 126 to reach the pre-determined temperature.

10 The biochar formed in carbonization chamber 126 is then collected in a collection chamber 136. The collection chamber 136 may comprise a product levelling bar 138 which ensures that the biochar collected in the collection chamber 136 is evenly distributed in the collection chamber 136.

15 There is also provided a heat insulation panel 140 between the carbonization chamber 126 and the collection chamber 136. The heat insulation panel 140 may be made of any suitable heat insulating material. In particular, the heat insulation panel 140 ensures that the heat is retained within the carbonization chamber 126 and the collection chamber 136.

20 The system 100 also comprises a heat exchanger 142 between the heat exchanging unit 118 and the collection chamber 136. The heat exchanger enables heat from the formed biochar and within the collection chamber 136 to be supplied to the heat exchanging unit 118. In this way, the organic waste in the heat exchanging unit 118 may get heated since the heat exchanging unit 118 does not comprise any external heat source.

25 The heat exchanging unit 118 and the collection chamber 136 may be in fluid communication with a flu gas treatment system 144. In particular, pipes 146 and 148 enable gases from the heat exchanging unit 118 and collection chamber 136, respectively, to be channelled to the flue gas treatment system 144 before being vented out from outlet 150. The flue gas treatment system 144 may be any suitable system for treating flue gas. For example, the flue gas treatment system 144 may be as shown in Figure 4.

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Figure 2 shows an example of a crusher outlet sealing system. The seal may be a horizontal cylinder which along its horizontal axis is divided into three equal portions by three tetragons. The horizontal cylinder seal has two rounded sides, while the curved surface is removed. The cylinder is configured to rotate along its horizontal axis. When one portion of the cylinder is exposed to the inlet 102, the other two portions face the crusher 104 and provide a seal to the inlet 102, thereby preventing any odour from escaping the system 100. When the cylinder rotates the organic waste fed into inlet 102 goes into the crusher 104. In this way, the crusher 104 is sealed at all times.

Figure 3 shows an example of a liquid filtration system 114 for treating waste liquid comprised in a container body 200. The liquid filtration system 114 comprises a sediment basket 202. The sediment basket 202 comprises outlets 204a and 204b to allow overflow liquid to flow into a sand filter basket 206. The sand filter basket 206 may comprise any suitable material such as rocks 206a, coarse sand 206b and fine sand 206c. The system 114 then flows into an activated carbon basket 208 which comprises a granular activated carbon filter 208a. Treated liquid may then flow out of the container body 200 from outlets 210a and 210b.

The liquid filtration system 114 may also comprise a back flushing system for regenerating the sand filter basket 206. The back flushing system may comprise a flushing water inlet 212, a flushing funnel 214 and a flushing water outlet 216.

Figures 4A and 4B show examples of a flue gas treatment system 144 for treating flue gas from the carbonization chamber 126 and the collection chamber 136. The choice of the flue gas system selected may depend on the composition of the flue gas to be treated. For example, the choice of the flue gas system may be based on whether the flue gas comprises more carbon monoxide (CO) as compared to nitrogen oxide gases (NO_x), or whether the flue gas comprises more NO_x as compared to CO. The flue gas system as shown in Figure 4A is selected if the flue gas comprises more CO than NO_x, while the flue gas system as shown in Figure 4B is selected if the flue gas comprises more NO_x than CO. In both Figures 4A and 4B, like parts are referred to using the same reference numeral.

In the flue gas treatment systems 144a and 144b, there is provided a flue gas inlet 300 through which flue gases to be treated are provided to the systems 144a and 144b. The flue gas entering the systems 144a and 144b go through a basic gas scrubber 302

where all basic gases such as NH_3 are removed before entering an acidic gas scrubber 304. In the acidic gas scrubber, the acidic gases such as SO_2 , SO_3 , H_2S and HCl are removed. Then the flue gas passes through a filter bag 306 to remove any particulates. Thereafter, CO , NO_x and hydrocarbons are removed.

- 5 In the case of system 114a, the flue gas to be treated comprises CO in excess of NO_x . Accordingly, to remove the CO , NO_x and some hydrocarbon, a three-way converter 308 is used. In the case of system 114b, the flue gas to be treated comprises NO_x in excess of CO . Accordingly, to remove the NO_x , CO and some hydrocarbon, a selective catalytic reduction (SCR) catalyst 310 together with a two-way converter 312 is used.
- 10 Following the catalytic converters 308 and 312, the remaining hydrocarbons in the flue gas such as formaldehyde and other trace of harmful gases may be removed by a hydrocarbon adsorbent 314. Any suitable hydrocarbon adsorbent may be used. For example, the hydrocarbon adsorbent may be granular activated carbon. Any mercury remaining in the flue gas may then be captured by a mercury adsorbent 316. The
- 15 mercury adsorbent may be any suitable adsorbent such as sulphur or iodine infused activated carbon. Finally, the treated flue gas may be vented out of the system via an outlet vent 150.

According to a second aspect, there is provided a method of treating organic waste using the system described above.

- 20 According to a third aspect, there is provided a method for treating organic waste, the method comprising:
- providing organic waste to a crusher through an inlet;
 - crushing the organic waste to reduce size of the organic waste;
 - heating the organic waste to increase temperature of the organic waste;
 - 25 and
 - torrefying the organic waste to form biochar.

The organic waste may be any suitable organic waste for the purposes of the present invention. For example, the organic waste may be as described above.

The crushing comprises reducing the organic waste into smaller size. At the same time, during the crushing, the liquid content comprised in the organic waste may be reduced as the crushing causes the liquid within the organic waste to be squeezed out, thereby drying the organic waste. The crushed organic waste may then be transferred onto a conveyor to be transferred to a pre-treatment chamber for heating.

The crushing may be carried out by any suitable means. For example, the crusher may be carried out in a crusher comprising a blade configured for crushing material into smaller pieces. The crusher may be any suitable crusher. In particular, the crusher may be as described above.

The method may further comprise a separating the organic waste prior to the crushing. In particular, the separating may comprise separating any metal components within the organic waste. In this way, the metal components may be recycled. Further, by separating the metal components from the rest of the organic waste, the blade of the crusher may be protected from the hard metal components. The separating may be carried out by any suitable means. For example, the separating may be by a metal detector and/or metal remover. In particular, the metal detector may comprise an electromagnet.

The conveyor onto which the crushed organic waste is transferred following the crushing may be any suitable conveyor. According to a particular aspect, the conveyor may be a moving filter belt. In particular, the filter belt enables any liquid expelled from the organic waste during the crushing to flow through the filter belt and into a waste liquid collection chamber.

The heating may be carried out at a pre-determined temperature. According to a particular aspect, the heating may be carried out in a step-wise manner. For example, the heating may be carried out in two or more steps. In particular, the heating may be carried out in two steps – a first heating and a second heating. The heating may be carried out in a pre-treatment chamber. The first heating and the second heating may be in separate units within the pre-treatment chamber. In particular, the pre-treatment chamber may comprise a heat exchanging unit and a pre-heating unit. Even more in particular, the first heating may be carried out in a heat exchanging unit and the second heating may be carried out in a pre-heating unit.

The first heating may be carried out in a heat exchanging unit. The first heating may be carried out without any external heat source and the heat for the first heating may be supplied by hot gases comprised within the heat exchanging unit. In particular, the hot gases within the heat exchanging unit may heat up the organic waste to a suitable temperature of about 80-100°C.

During a first heating, the crushed organic waste may be heated at a temperature in the range 50-100°C. In particular, the first heating may comprise heating the crushed organic waste at a temperature of: 55-95°C, 60-90°C, 65-85°C, 70-80°C, 72-75°C. Even more in particular, the first heating may comprise heating the crushed organic waste at a temperature of about 80-100°C.

The second heating may be carried out in a pre-heating unit. In particular, the moving conveyor enables the organic waste to be transported from the heat exchanging unit to the pre-heating unit. Even more in particular, the moving filter belt may be joined to a moving belt in the heat exchanging unit. The moving belt may have 3-sided blocks, a front bottom blade and back top block.

The second heating may be carried out with an external heat source supplying heat to heat up gases comprised within the pre-heating unit. The external heat source may be any suitable heat source. In particular, the hot gases within the pre-heating unit may heat up the organic waste at a suitable temperature of about 100-320°C. The temperature at which the organic waste may be heated in the pre-heating unit may be 120-300°C, 150-280°C, 180-250°C, 200-230°C, 210-220°C. Even more in particular, the temperature in the pre-heating unit may be about 200-280°C.

The organic waste may be comprised in the heat exchanging unit and the pre-heating unit for a pre-determined period of time. The pre-determined period of time may change depending on the temperature conditions within the heat exchanging unit and the pre-heating unit. The average pre-determined period of time may be about 5-120 minutes. In particular, the average pre-determined period of time may be about 10-30 minutes. According to a particular aspect, the average pre-determined period of time may be determined by the speed of the conveyor transferring the organic waste from the crusher to the pre-treatment chamber. The speed of the conveyor may be adjusted

by a controller. The controller may be a temperature controller. The temperature controller may in turn be connected to the heat source.

In particular, the temperature controller measures the temperature within the heat exchanging unit and the pre-heating unit. If the temperature within the pre-heating unit falls below the pre-determined temperature, the temperature controller may sound an alarm and/or adjust the speed of the conveyor to ensure that the organic waste stays within each of the heat exchanging unit and the pre-heating unit for a longer period of time. The temperature controller may further cause the external heat supply to supply more heat to the pre-heating unit to increase the temperature within the pre-heating unit to the pre-determined temperature.

Following the heating in the pre-heating unit, the method further comprises torrefying the organic waste in a carbonization chamber to form treated organic waste in the form of biochar. Accordingly, the pre-heated organic waste may be transferred from the pre-heating unit to a carbonization chamber. The torrefying may be carried out with an external heat source supplying heat to heat up gases comprised within the carbonization chamber. The external heat source may be any suitable heat source. In particular, the hot gases within the carbonization chamber may heat up the organic waste at a suitable temperature of about 280-450°C. The temperature at which the organic waste may be heated in the carbonization chamber may be 290-440°C, 300-430°C, 310-420°C, 320-410°C, 330-400°C, 340-390°C, 350-380°C, 360-370°C. Even more in particular, the temperature in the carbonization chamber may be about 350-400°C.

The torrefying may comprise torrefying the organic waste in the presence of an additive. The additive may be any suitable additive for the purposes of the present invention. For example, the additive may be an inert gas. In particular, the inert gas may be nitrogen gas, argon, helium gas, or a combination thereof. In this way, the resulting biochar produced from the torrefying may have a higher degree of carbon content.

The organic waste may be comprised in the carbonization chamber for a pre-determined period of time. The pre-determined period of time may change depending on the temperature conditions within the carbonization chamber. The average pre-

determined period of time may be about 5-120 minutes, preferably about 15-30 minutes. According to a particular aspect, the average pre-determined period of time may be determined by the speed of the conveyor transferring the organic waste from the pre-treatment chamber to the carbonization chamber. The speed of the conveyor
5 may be adjusted by a controller. The controller may be a temperature controller. The temperature controller may in turn be connected to the heat source.

In particular, the temperature controller measures the temperature within the heat carbonization chamber. If the temperature within the carbonization chamber falls below the pre-determined temperature, the temperature controller may sound an alarm and/or
10 adjust the speed of the conveyor to ensure that the organic waste stays within the carbonization chamber for a longer period of time. The temperature controller may further cause the external heat supply to supply more heat to the carbonization chamber to increase the temperature within the carbonization chamber to the pre-determined temperature to ensure treatment of the organic waste and formation of
15 biochar.

According to a particular aspect, the heating is carried out in the presence of the inert gas supplied to the carbonization chamber. The inert gas supplied to the carbonization chamber for the torrefying may flow to the pre-treatment chamber. The torrefying may also produce steam which, together with the inert gas, may flow to the pre-treatment
20 chamber. The heat energy from the inert gas and steam as a result of the torrefying may be utilised to heat the organic waste in the heat exchanging unit. The inert gas and the steam may be discharged through an outlet in the heat exchanging unit.

The method further comprises transferring the formed biochar to a collection chamber. The collection chamber is adjacent the pre-treatment chamber, thereby allowing heat
25 exchange to continue between the collection chamber and the pre-treatment chamber. The heat in the collection chamber may be from the formed biochar. The heat exchange may be by way of a heat exchanger. In particular, the heat exchange may be between the collection chamber and the heat exchanging unit. The heat exchange between the collection chamber and the heat exchanging unit may enable gases within
30 the heat exchange unit to get heated up, thereby heating the organic waste passing through the heat exchange unit. The heat exchange between the collection chamber and the heat exchanging unit also enables the formed biochar to cool down. The

method of the present invention therefore allows heat energy to be recycled, therefore cutting down on the amount of heat to be supplied by an external heat source, making the method more environmentally friendly.

According to a particular aspect, the method further comprises treating the waste liquid
5 obtained from the crushing. The treating may be in a liquid filtration system. Any suitable liquid filtration system may be used for the treating. In particular, the liquid filtration system may be as described above. Even more in particular, the liquid filtration system may be as shown in Figure 3. The treating may comprise treating the waste liquid according to local regulations before being discharged.

10 According to a particular aspect, the method may further comprise treating flue gas produced during the torrefying. The treating may be in a flue gas treatment system. For example, the method may comprise treating the inert gas and steam before being discharged. In particular, the outlet of the heat exchanging unit may be connected to the flue gas treatment system. The collection chamber may be connected to the flue
15 gas treatment system. In this way, the gases from the method of the present invention may be adsorbed by the flue gas treatment system to minimise odorous and/or environmentally harmful gas emission. In particular, the flue gas treatment system may comprise adsorbing solutions and/or solid cartridges for odour removal.

Any suitable flue gas treatment system may be used for the treating. In particular, the
20 flue gas treatment system may be as described above. Even more in particular, the flue gas treatment system may be as show in Figure 4.

The advantage of the method of the present invention is that the crushing enables most of the water content of the organic waste fed through the inlet to be removed. In this way, the pre-treatment time for pre-treating the organic waste may be reduced as less
25 drying is required prior to the torrefying. Further, less heat energy is required for drying the organic waste in view of the crushing. This makes the method of the present invention more time and energy efficient.

The method of the present invention may also be a continuous method and this makes the method an easy method for an operator. In particular, a user of the method only
30 needs to provide the organic waste to the inlet and collect the formed biochar from the collection chamber at regular intervals.

The method of the present invention will now be described in relation to the organic waste treatment system 100. Organic waste is fed through an inlet 102 of an organic waste treatment system 100. Separating of the organic waste is carried out at the inlet 102 using a metal detector 108 to separate the metal waste from the rest of the organic waste. The remaining organic waste is then fed to a crusher 104 to crush the organic waste and to reduce the size of the organic waste. Much of the liquid comprised within the organic waste is squeezed out of the organic waste and this liquid is collected in a waste liquid collection chamber 112. The waste liquid collection chamber 112 may further comprise a waste water filtration system 114 (described below). From the crusher 104, the crushed organic waste drops onto a first conveyor 110 in the form of a moving filter belt. The excess liquid from the crushed organic waste may continue to flow into the waste liquid collection chamber 112. The first conveyor 110 transports the crushed organic waste to a pre-treatment chamber 116 comprising a heat exchanging unit 118 and a pre-heating unit 120. The first conveyor 110 is joined to a second conveyor 124 at the pre-treatment chamber 116. Accordingly, the organic waste transfers from the first conveyor 110 to the second conveyor 124.

At the heat exchanging unit 118, a first heating of the crushed organic waste takes place. In particular, the first heating may be at a temperature of about 80-100°C. The first heating is to increase the temperature of the organic waste, therefore further drying the organic waste following the crushing. In particular, the first heating of the organic waste is by using the heat of the gases comprised within the heat exchanging unit 118.

After a pre-determined period of time, the second conveyor 124 transports the organic waste to a pre-heating unit 120 for a second heating of the crushed organic waste. The second heating may be at a temperature of about 200-280°C. The second heating is to further increase the temperature of the organic waste to further dry the organic waste before the torrefying. As the second heating is at a higher temperature, an external heat source 132 may be required to provide further heat to the pre-heating unit 120. The heat provided by the heat source 132 is to heat the gases within the pre-heating unit 120, which in turn will heat the organic waste passing through the pre-heating unit 120.

After a pre-determined period of time, the second conveyor 124 transports the organic waste to a carbonization chamber 126 for torrefying the organic waste to form biochar.

The total pre-determined period of time the organic waste is in the pre-treatment chamber 116 may be about 10-30 minutes. However, the pre-determined period of time may vary depending on the speed of the second conveyor 124 which may be dependent on the temperatures of the heat exchanging unit 118 and the pre-heating unit 120.

The torrefying may be at a temperature of about 350-400°C. As the torrefying is at an even higher temperature than the pre-heating unit 120, an external heat source 134 may be required to provide further heat to the carbonization chamber 126. The heat provided by the heat source 134 is to heat the gases within the carbonization chamber 126, which in turn will torrefy the organic waste passing through the carbonization chamber 126. The organic waste may be in the carbonization chamber 126 for torrefying the organic waste for a pre-determined period of time. The pre-determined period of time may be about 15-30 minutes. However, the pre-determined period of time may vary depending on the speed of the second conveyor 124 which may be dependent on the temperature of the carbonization chamber 126.

The torrefying in the carbonization chamber 126 may be carried out in the presence of an additive. The additive may be supplied to the carbonization chamber 126 through an inlet 130. The additive may be an inert gas. In particular, the additive may be nitrogen gas.

The formed biochar from the carbonization chamber 126 following torrefying the organic waste is then collected in a collection chamber 136. Heat exchanger 142 enables heat exchange between the collection chamber 136 and the heat exchanging unit 118. In particular, heat from the biochar formed in the carbonization chamber 126 and collected in the collection chamber 136 is transferred by way of the heat exchanger 142 to the gases comprised in the heat exchanging unit 118.

The heaters 132 and 134 are connected to temperature controllers (not shown). The temperature controller is in turn connected to the second conveyor 124. When the temperature controller detects that the temperatures of the pre-heating unit 120 and/or the carbonization chamber 126 falls below the pre-determined temperature, the temperature controller will adjust the speed of the second conveyor 124 to ensure that the residence time of the organic waste in the pre-heating unit 120 and/or the carbonization chamber 126 is increased so that the organic waste is sufficiently heated

and/or torrefied. At the same time, the temperature controller will cause the heaters 132 and 134 to be activated to supply more heat to the pre-heating unit 120 and/or the carbonization chamber 126. Likewise, if the temperature of the pre-heating unit 120 and/or the carbonization chamber 126 is above the pre-determined temperature, the temperature controller may adjust the speed of the second conveyor 124 to ensure that the residence time of the organic waste in the pre-heating unit 120 and/or the carbonization chamber 126 is reduced accordingly. The temperature controller may also cause the heaters 132 and 134 to switch off as additional heat may not be required.

The nitrogen gas, steam and flue gases from the carbonization chamber 126 and the pre-treatment chamber 116, and gaseous emissions from the collection chamber 136 are routed to a flue gas treatment system 144 via pipes 146 and 148, respectively. The flue gas treatment system 144 may be as shown in Figure 4. After the gases undergo treatment in the flue gas treatment system 144, the cleaned gases are vented out of the system 100 via outlet 150.

The waste liquid collected in the waste liquid collection chamber 112 is treated in the liquid filtration system 114. The liquid filtration system 114 is as shown in Figure 3. In particular, waste liquid from the crusher 104 and flowing through the first conveyor 110 flows to a sediment basket 202. In the sediment basket 202, the sludge 218 settles at the bottom and clear liquid overflows to a sand filter basket 206. The sand filter basket 206 comprises rocks 206a, coarse sand 206b and fine sand 206c. Liquid from the sand filter basket 206 then flows down to a granular activated carbon filter 208a comprised in an activated carbon basket 208. After the sediment, sand filter and carbon filter, waste liquid is clarified as clean water and flows to the bottom of the waste liquid collection chamber 112 and discharged out as clean liquid from outlets 210a and 210b.

The sand filter basket 206 may be regenerated by a back flushing system comprising a flushing water inlet 212, a flushing funnel 214 and flushing water outlet 216.

The present invention provides several advantages. In particular, the organic waste treatment system and method for treating organic waste have a low carbon footprint since the system and method utilise minimal external energy in view of the use of recycling the heat energy generated during the organic waste treatment process. The system and method enable organic waste to be reduced to a useful form. The system

and method also enable any flue gases to be suitably handled, thereby eliminating release of unpleasant process related gases and odours. Further, compared to conventional carbonization/torrefaction treatment processes, the present method can treat the organic waste in a much shorter time.

5 Further, it was surprisingly found that having three heating zones as shown in Figure 1 (i.e. heat exchanging unit, pre-heating unit and carbonization chamber) was much better in energy saving than two heating zones. When there are only two heating zones, one for pre-heating and one for torrefaction, two situations may exist. The first situation is that, if the pre-heating temperature is between 100 and 250°C, particularly
10 about 180°C, the steam temperature from the carbonization/torrefaction is only around 100°C which would not be sufficient for transferring heat to the pre-heating unit, thus wasting the heat of steam which consumes most of the energy in the pre-heating and torrefaction processes.

The second situation is that, if the pre-heating temperature is below 100°C, particularly
15 about 98°C, most of the moisture content in the pre-heating unit could not be vaporized which requires 100°C. Therefore, when the feedstock is transferred from the pre-heating unit to the carbonization chamber for torrefaction, full evaporation would still be needed which requires most energy. This affects the temperature of carbonization chamber, which requires high energy input to maintain a high temperature with a high
20 mass loading for vaporization, and the steam energy from the carbonization chamber may not be fully utilized in the pre-heating unit because of only a small portion of moisture being vaporized. When there are three heating zones, the first for heat exchange up to 100°C, the second for pre-heating from 100 to 250°C, and the third for torrefaction from 280 to 450°C, the heat energy recycle is much more efficient. Most
25 moisture (most energy consumption on it) is vaporized in the pre-heating unit and the steam generated carries the energy back to the heat exchanging unit to heat up the feedstock up to 100°C, which fully utilizes the recycled heat. The pre-heating unit also buffers the temperature difference between the heat exchanging unit and the carbonization chamber so that the temperature of the carbonization chamber is stable
30 for the torrefaction. Furthermore, since most moisture is removed in the pre-heating unit, much less energy needed in the carbonization chamber due to much lower mass although the temperature is high.

Whilst the foregoing description has described exemplary embodiments, it will be understood by those skilled in the technology concerned that many variations may be made without departing from the present invention.

Having now generally described the invention, the same will be more readily understood through reference to the following examples which are provided by way of illustration, and are not intended to be limiting.

EXAMPLE

The efficiency of the pre-heating unit and the carbonization chamber were evaluated by investigating the carbon conversion fraction of the product compared with feedstock. In particular, two tube furnaces with good temperature control and gas flow control were used to represent the pre-heating unit and the carbonization chamber.

Table 1 lists the treatment conditions (temperature, time) used in the two chambers during the experiments.

Experiment No.	Pre-heating unit		Carbonization chamber	
	Temperature (°C)	Time (minutes)	Temperature (°C)	Time (minutes)
1	200	30	-	-
2	200	30	300	15
3	200	30	300	30
4	200	30	350	15
5	200	30	350	30
6	200	30	400	15
7	200	30	400	30
8	200	30	500	24 hours

Table 1: Treatment conditions used in the pre-heating unit and the carbonization chamber

The initial sample weight was 6 g with an initial moisture content of 67%. The carbon composition in the same was 19.7% based on dry weight.

The carbon conversion fraction (the extent of solid-phase carbon conversion), which reflects the efficiency of the treatment process may be calculated using the following equation:

$$\eta = (C_{\text{feed}} - C_t) / (C_{\text{feed}} - C_{\infty})$$

where C_{feed} is the mass of carbon in the initial feedstock, C_t is the carbon in the recovered solids at time t , and C_{∞} is the carbon in the recovered solids after prolonged torrefaction (more than 24 hours).

- 5 Figure 5 shows the results of the carbon conversion fraction calculated from the above experiments.

The results show that for the same feedstock (initial carbon content is about 20%), after pre-heating treatment for 30 minutes at 200°C without subsequent torrefaction, the carbon conversion fraction is around 60%. If the dried organic waste further undergoes
10 the torrefaction treatment after pre-heating treatment, the carbon conversion fraction will be increased to more than 90%, which indicates that the combined pre-heating/torrefaction process is effective. The temperature of the torrefaction chamber is preferably 350 to 400°C, and the average residence time of the organic waste in the carbonization chamber is preferably 15-30 minutes.

- 15 According to calculations, the final biochar product following the torrefaction process has a calorific value of around 6000 kcal/kg in a range of 4700-7000 kcal/kg. After considering the daily electricity energy consumption of running the system of the present invention, the daily calorific gain is 83,820 kcal. Accordingly, the biochar formed from the method of the present invention may be used as a good source of
20 energy.

Claims

1. An organic waste treatment system comprising:

- an inlet for receiving organic waste;
- a crusher coupled to the inlet for reducing the size of the organic waste;
- 5 - a pre-treatment chamber for pre-treating the organic waste, the pre-treatment chamber comprising a heat exchanging unit and a pre-heating unit; and
- a carbonization chamber for treating the pre-treated organic waste to form biochar,

10 wherein the system comprises three heating zones for stage-wise heating of the organic waste the three heating zones comprising a first heat exchanging zone at a temperature of 80-100°C and comprising the heat exchanging unit, a second heating zone at a temperature of 100-320°C for heating the organic waste and comprising the pre-heating unit, and a third torrefaction zone at a temperature of 280-450°C for
15 torrefaction of the organic waste and comprising the carbonization chamber.

2. The system according to claim 1, further comprising a collection chamber for collecting the formed biochar.

20 3. The system according to claim 2, further comprising a heat exchanger between the pre-treatment chamber and the collection chamber.

4. The system according to any preceding claim, wherein the carbonization chamber comprises an inlet for receiving an additive.

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5. The system according to claim 4, wherein the additive is an inert gas.

6. The system according to claim 4 or 5, wherein the additive is nitrogen gas, argon, helium gas, or a combination thereof.

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7. The system according to any preceding claim, further comprising a heat source for heating gas comprised in the carbonization chamber and the pre-heating unit.

8. The system according to any preceding claim, further comprising a separator at the inlet, the separator configured to separate metal from the organic waste received through the inlet.

5 9. The system according to any preceding claim, further comprising a conveyor configured to move organic waste received from the inlet through the pre-treatment chamber and the carbonization chamber.

10 10. The system according to claim 9, further comprising a temperature controller configured to measure temperatures of the pre-treatment chamber and the carbonization chamber and adjust speed of the conveyor.

11. The system according to any preceding claim, wherein the crusher comprises a seal to prevent any odour from the organic waste from escaping into the atmosphere.

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12. The system according to any preceding claim, further comprising a waste liquid collection chamber in fluid communication with the crusher for collecting waste liquid from the crusher.

20 13. The system according to claim 12, wherein the waste liquid collection chamber comprises a liquid filtration system for treating waste liquid.

25 14. The system according to any of claims 2 to 13, further comprising a flue gas treatment system in fluid communication with the collection chamber for treating flue gas from the carbonization chamber.

15. A method of treating organic waste using the system according to any preceding claim.

30 16. A method of treating organic waste, the method comprising:
- providing organic waste to a crusher through an inlet;
- crushing the organic waste to reduce size of the organic waste;
- heating the organic waste to increase temperature of the organic waste;
and

- torrefying the organic waste to form biochar,
wherein the heating comprises two stage-wise heating of the organic waste prior to a
third heating during the torrefying, the stage-wise heating comprising a first heating at a
temperature of 80-100°C, a second heating at a temperature of 100-320°C and the
5 torrefying comprises torrefying at a temperature of 280-450°C.

17. The method according to claim 16, wherein the torrefying comprises torrefying
the organic waste in presence of an inert gas.

10 18. The method according to any of claims 16 to 17, further comprising separating
metal from the organic waste received through the inlet prior to the crushing.

19. The method according to any of claims 16 to 18, further comprising treating
waste liquid obtained from the crushing in a liquid filtration system.

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20. The method according to any of claims 16 to 19, further comprising treating flue
gas produced during the torrefying.