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(54) **Title**: PROCESS FOR TREATMENT OF MATERIALS IN A VESSEL

(57) **Abstract**: The invention relates to a process to treat materials in a vessel at elevated temperature and pressure, wherein the vessel is loaded with compactable material to be treated, the material is preferably size reduced to at most 30 cm in at least one dimension, and wherein preferably, the material is subjected to at least one compacting stage and additional filling step, and filling is performed preferably at a speed of rotation of the vessel between 4 and 10 rpm, wherein the material after the filling step(s) is subjected to the main cooking or treatment cycle, and the treated material from the vessel is obtained, which treated material preferably is classified into one or more useful fractions.

PROCESS FOR TREATMENT OF MATERIALS IN A VESSEL

The invention relates to a process for treatment of materials in a vessel at elevated pressure and temperature. Suitable materials are waste such as municipal solid waste (MSW), Commercial & Industrial or medical wastes.

Waste, in particular municipal solid waste (MSW) and similar types of commercial waste, is an increasing burden on landfills and other forms of waste treatment. Part of the waste stream may be recycled through separated collection. Part of the landfill may be circumvented by incineration; however this is very costly and may have negative environmental impacts. One of the alternatives suggested is treating the waste in a vessel, under pressure, with heat and/or steam while tumbling the content in order to break down the organic content and enable easier separation while the waste is sterilized. Several examples of this idea exists, such as disclosed in EP 0771237 , US 4844351, US 6306248, US 4974781, WO 03/09299, WO 2004/018767, WO 03/025101, WO 2008/010970, WO 2008/112168 and WO 2008081028..

The technology has interesting potential: The organic fibres can be used as clean biomass fuel or compost; the glass/grit fraction can be used either by separating the glass for uses in recycled glass products, or it can be used as recycled aggregates. The municipal waste does not have to be pre-selected or pre-treated, and is reduced to about 30 volume% or more of its original size. Further, when fibres are separated, and other useful materials are recycled, landfill can be limited to less than 10 volume% of the original waste.

The technology, however, has several challenges. One is that it requires some capital, and it is important to maximise the amount of waste that can be processed by a given plant. Another is that it is useful to reduce the amount of energy used during the process and thus improve its economic returns. A third is that it can be useful to reduce the amount of water or steam consumed by the process per tonne of waste, for environmental considerations and/or to improve economic returns. Finally it can be useful to reduce the amount of water in the final fibre product to better fit it for some final market uses (to improve the calorific value as a fuel, for example).

It is a first object of the invention to improve the overall economics of the process in one or more of the above mentioned aspects.

Previous methods suggested for overcoming one or more of these four challenges have to date involved the purchase of additional equipment, the consumption of more primary energy or some other compromise.

It is another object of the invention to further improve the overall economics of the process in one or more of the above mentioned aspects without adding further equipment.

The improvements to the basic technologies as described in this invention allow for all four of the above improvements.

According to a first aspect of the present invention, the process to treat materials in a vessel at elevated temperature and pressure comprises the following steps: (a) treating household or commercial waste such that substantially all waste has been reduced to a size of about 30 cm or less in at least one dimension wherein the size reduction is not smaller than to 10 cm in at least one dimension, and (b) feeding the treated waste into an vessel till at least 70 vol% full, which vessel is tilted between 10° and 60° from the horizontal, (c) after filling the vessel, the material is subjected to the main cooking or steam treatment cycle, and (d) the treated material from the vessel is obtained, which treated material preferably is classified into one or more useful fractions.

Preferably, the treatment of waste to achieve the required size is performed with a slow-rotating shredding apparatus. This is preferred over a bag splitter, as a bag splitter does not ensure size reduction of other than part of the thin plastic film. The slow-rotating shredding apparatus is furthermore preferred over fast-rotating shredding apparatus, because the impact on the waste is less in the slow-rotating shredding apparatus. A low impact is preferred, because batteries and the like are not damaged, and heavy metals do not leak into the waste. However, any apparatus that results in waste with about 30 cm or less in size, in one dimension can be used in the present process.

The use of this size reduction has as a further advantage that so called “bridging” is precluded. Bridging takes place even in large vessels with large doors, and when rotating and at an angle. Precluding bridging is a very important advantage as bridging causes to preclude full loading of a vessel as the vessel seems to be fully filled.

According to another embodiment of the present invention, the process to treat materials in a vessel at elevated temperature and pressure comprises the following steps:

(a) the vessel is loaded with compactable material to be treated, and (b) the material is subjected to at least one compacting stage the compacting step being performed for some time and at an elevated temperature to have the material reduced, and (c) additional filling step, (d) the material after the compacting and additional filling step(s) is subjected to the main cooking or treatment cycle, and (e) the treated material from the vessel is obtained, which treated material preferably is classified into one or more useful fractions.

In a preferred embodiment, the compacting step is performed for sufficient time and at a sufficient temperature to have the material reduced by at least about 10 vol%, after which step the additional material occupies at least 5 vol%.

In a further preferred embodiment, the vessel is closed during the compacting step.

The compacting step is preferably performed in such a controlled way that little or no VOC's or steam is emitted into the environment.

In another embodiment, the vessel (having helical flights) during loading is rotating at a speed which is higher then normally taught in the prior art. The prior art, notably US5445329, describes a rotation of 2 rpm for loading and unloading. The main cooking step is generally performed in horizontal position with alternating clockwise and counterclockwise rotation at a speed between 6-10 rpm. Loading and unloading generally takes place at an angle of +45° (between 20-60° with respect to the horizontal) for loading, and preferably -20° for unloading (between -5 and -40°). At such angles, the bearings are under sideward's stress, and the speed of rotation needs to be low. The present inventors realized that loading at a speed of 4-8 rpm leads to a substantially higher filling rate. The increased speed is also of use in filling vessels that are about horizontal. It is furthermore preferred for an efficient use of the autoclave, to unload at a speed of minus 4-8 rpm (for a vessel with one door), or 4-8 rpm for a vessel with two doors on opposite sides. A positive rotation is rotation in which the flights in the vessel cause the material to be pushed away from the door through which the opening takes place.

It appeared to be possible to increase loading with about 5 wt% or more by increasing the speed from 2 rpm to 4 or 6 rpm.

In a further embodiment of the invention, above described measures of size reduction, and/or loading at an angle and compacting, and/or increasing the speed of rotation are used in combination of two of these measures, or all three can be combined.

In a further embodiment, the invention is embodied in a waste treatment system comprising at least one rotatable and tiltable vessel of a size N m^3, the vessel being at least 50 m^3 in size (hence, N is at least 50), wherein the vessel is resting on bearings, the bearings are able to withstand loading of more than 0.4*N tonnes, preferably more than 0.45*N tonnes, and even more preferable, 0.5*N tonnes. The bearings in the prior art generally are designed to withstand standard loading schemes. The MSW and other commercial waste has a relatively low density, so, (for example) the bearings of a 60 m^3 rotatable vessel are designed to bear at most 20 tonnes. The inventors realized that substantially extended loading allows significant optimisation of the process economy with very low investment (if any), and that therefore, the waste treatment system should comprise relatively strong bearings.

More in particular, according to the present invention, the following steps are performed in a process to treat materials in a vessel at elevated temperature and pressure

(1) Materials preferably are reduced in size such that substantially all particles have a size of about 30 cm or less in at least one dimension
(2) preferably, the vessel is inclined to be loaded, at about 10° or higher, up to about 60° but more usually up to about 45° or more from the horizontal;
(3) preferably, the vessel is rotated at a speed of 4 rpm or more, and generally less than about 10 rpm.
(4) the vessel is loaded with the material to be treated to at least 50 volume% full but preferably at least 70%, and even more preferably at least 75% and even more preferably at least about 95 volume% full
(5) preferably, the vessel is closed
(6) optionally, a vacuum up to -0.9 barg is applied
(7) preferably the material is heated via the addition of steam, indirect heating or via any other method, generally to a temperature of 70°C to 150 °C but more preferably 95 °C to 110 °C. This can be done under pressure of about 0.1 barg or more up to 3barg but preferably below 0.5barg if desired. Heating can start at any time in the sequence, including before the material is charged to the vessel. In case steam is used to heat the material, it is preferred to start the addition of substantial amounts of steam only after closing of the door.
(8) the material inside the vessel preferably is agitated by rotation of the vessel,

intermittently if required, as soon as loading has commenced

(9) optionally, if the vessel can be inclined or declined along its axis, (in the art usually but not limited to +60° to -20° relative to the horizontal) it may be tipped to an incline optimum for this part of the process at any stage, but usually after loading has finished

(10) the vessel is held, usually while rotation and agitation is progressing, for between 1 and 45 minutes, more preferably between 3 and 15 minutes and most preferably about 5 min or more at elevated temperature;

(11) the vessel is depressurised and may be cooled, and the door opened. The original material has now been pre-heated and compacted significantly generally about 25% or more, mostly about 30% or more, up to 50%.

(12) At least about 5% of further material (preferably about 20% or more, more preferably about 30% or more), which may be different to the first if desired, is further loaded into the vessel

(13) the vessel is again closed and optionally steps 1 to 10 are then repeated one or more times;

(14) when sufficient loading has taken place the main cooking or steam treatment cycle, for example as described in the prior art, is initiated

According to the first aspect of the present invention, the process to treat materials in a vessel at elevated temperature and pressure comprises the following steps: treating MSW such that substantially all waste has a size of about 30 cm or less in at least one direction. The size reduction is preferably to not smaller than 10 cm in at least one dimension, as that requires relatively high energy input. Preferably, the size reduction is to between 20-30 cm in at least one dimension.

The waste that is reduced in size is thereafter fed into the vessel, which vessel is tilted between +10° and +60° from the horizontal. Preferably, filling the vessel is executed till the vessel is filled for at least 70 volume%. The tilt is important for achieving a high volume% fill. Generally, it is difficult to fill a vessel which remains horizontal to more than 50 volume%. It is preferred to have the vessel tilted to about 25° or more, and even more preferably about 30° or more. Although a higher value of the angle improves loading, it has the disadvantage of increasing expense of the system, as the building and loading equipment needs to be placed high. Hence, it is preferred to have a loading angle of about 55° or less, and even more preferred of about 50° or less.

Preferably, the treatment of waste to achieve the required size is performed with a slow-rotating shredding apparatus

According to the another embodiment of the present invention, the to be treated material is pre-heated and compacted significantly generally about 20% or more, mostly about 30% or more, up to 50%, which allows further introduction of waste materials. The compacting step requires generally less than 20% of the time of a total cycle or less, preferably 15% or less; longer times generally allow for further reduction to for example 30-50%. The further introduction of waste allows for a very significant increase of plant capacity.

Some prior art suggests to compact the waste somewhat during filling. For example, US 5540391 describes to tilt and rotate the vessel during filling; US 6397492 describes to keep the vessel heated, and to introduce steam during loading; EP0908190 describes to comminute the waste, while WO2008082018 suggests to use a bag splitter or press. These methods are either hardly effective, require extensive wasted steam treatment and/or require additional high investment. None of the prior art describes a suitable shredding step in combination with filling in a tilted vessel. Equally, none of the prior art describes a compaction step and thereafter a refill, wherein the compaction step requires the treatment of the content of the vessel for several minutes at 70 °C or higher.

According to yet another embodiment of the present invention, the vessel (having helical flights) is rotating at a speed of between 4 and 8 rpm during loading.

The advantage of the shredding treatment and/or compaction stage and/or increased rotation is

(1) it increases the charge of material that is possible to be treated in the vessel in any given batch, and thus can improve the throughput and economic returns of the technology at little or no additional Capital cost. Normally, a batch treatment takes between 150 and 350 minutes for a 20 tonne batch, with less or more time required for smaller and larger batches respectively; now it is possible, by adding for example about 15 – 45 min to one cycle (for the compactation stage), or a shredder, or by increased rotation, to extend the capacity with about 10-30% or more; which is a significant advantage. For example, the time needed for the pretreatment step is about 3-15% of the period of the main process, and it can be about 5-10%.

(2) as a result of the increase of throughput, it reduces energy use per tonne of

material treated which improves the technology's cost or environmental position

(3) as a result of the reduced amount of energy per tonne of waste, if steam is used as one or more of the heating media, it reduces the quantity of moisture in the resultant products, especially the fibre product. This almost always improves its cost or performance characteristics, either because as a fuel it will have a higher calorific value and/or require less water to be extracted to obtain a target calorific value or because if a cost has to be paid to dispose of the fibre it will have less mass and therefore the disposal cost will be lower

(4) as a result of the reduced amount of energy per tonne of waste, the amount of steam required per tonne of waste processed is reduced, with a consequent economic and environmental benefit

(5) as a result of the reduced amount of steam necessary for treatment a tonne of waste, the amount of steam condensate arising from the vessels per tonne of waste processed is reduced, with a consequent economic and environmental benefit

This method is applicable to any enclosed autoclave-based heat- or steam-treatment process for waste and other products where it is desired to process and separate more useful fractions of a mixture of substances and where the materials introduced in the vessel are compactable. Known methods for treatment of compactable materials include (i) methods using pressure from atmospheric up to steam pressures including and beyond 4 barg like up to 6 or 8 barg (ii) methods using one or more of direct steam, hot gas or water, hot jackets and internal heated features, like flutes or helices, as a method of heating (iii) vessels where the waste is charged and discharged from the same or different ends (iv) methods where the contents are changed by chemical transformation (i.e. by a cooking process) or just dried and compacted.

Specific methods for which this invention is very suitable include processes as described in EP 0771237, US 4844351, US 6306248, US 4974781, WO 03/09299, WO 2004/018767, WO 03/025101, WO 2008/010970, WO 2008/112168 and WO 2008081028.

Materials that can be advantageously processed with the method of the present invention include wastes and other material from municipal, industrial or other sources such as medical facilities, agricultural and food waste or products, the products of kerbside recycling schemes or biomass from forestry and horticulture. It will be clear for the skilled person, that all sorts of compactable materials that need treatment in an autoclave are useful for the present invention. The invention will be further described for waste, but this is not to be construed as a limitation unless specifically stated.

In the usual embodiments of the autoclave technology, the process to treat these materials comprises some or all of the following steps:
(i) pretreating material to improve its properties if required
(ii) feeding waste material into a pressure vessel
(iii) agitating the vessel while applying heat to the contents of vessel via one of the methods above, to change the properties of the contents
(iv) cooling and/or depressurising the vessel
(v) discharging the vessel
(vi) classifying the treated waste to yield at least a fibrous fraction, further (optionally) yielding several fractions, such as shattered glass and grit, and larger parts such as plastics and metals
(vii) further separation and/or improvement of the fractions

The pretreatment step is optional, but may include selecting waste, such as for example taking out massive blocks of concrete, carpets and the like. Other pretreatment may include mixing of several waste streams.

In the first embodiment of the invention, the waste is shredded to the required size of about 10-30 cm maximum in at least one dimension.

Further pretreatment – preferably done after shredding - may include mixing several waste streams (if such waste stream has the required size) and/or pretreatment like adding water or chemicals to the waste.

Feeding of the waste material can be performed as is common in the art, like for example by a conveyer from a hopper. Preferably, the amount of waste is weighted such as to be able to adjust the process to the amount of waste in the vessel.

The vessel can be about horizontal during charging. In case of a horizontal vessel, rotation of the vessel having helical fins or paddles that causes the waste to be transported over the length of the vessel. However, it is preferred to have the vessel tilted above the horizontal, such that the opening of the vessel is at the higher point by for example about 5° or more, preferably about 10° or more, and even more preferably about 15° or more, and even more preferably about 30° or more. Sometimes, in particular with smaller vessels, it may be possible to have the vessel in a vertical position with the opening upwards, but generally, the tilt will be about 70° or lower, and even more often about 60° or lower. An angle of between 45° and 70° is considered optimal, in particular if the vessel can be rotated. In a preferred embodiment with a vessel of at least 50 m^3 in size, a 90° will be very expensive and not efficient, and a tilt of about 60° or less is preferred.

Preferably, the vessel is rotated during loading, which causes the waste to flow more easily and quickly into the vessel, with less chance of sticking or bridging during filling. Bridging could give the premature appearance that the vessel may be fully loaded. It appeared that with the pre-shredding as described above, bridging could be precluded, which is a distinct advantage.

In one preferred embodiment of the invention, rotation is carried out at a speed of about 4 rpm or more, and generally about 10 rpm or less, preferably about 8 rpm or less.

The vessel is loaded with the material to be treated to at least 50 volume% full but preferably at least 75 volume% and even more preferably at least about 95 volume% full.

When the vessel is filled, preferably, the door of the vessel is closed as to allow vacuum and pressure. Although the invention will also work without applying vacuum or pressure, the cycle time can be shortened if the non-atmospheric pressures can be used. Another advantage of working with a closed door is, that VOC's, and/or waste steam can be treated to preclude contamination of the environment.

Optionally, a vacuum of about -0.1 barg to up to -0.9 barg, preferably about -0.4 to -0.8 barg is applied. This has the advantage of withdrawing VOC's, which can be treated to preclude emission in the environment. Applying vacuum has the further advantage that steam that is thereafter introduced is more effective because it is not diluted by air.

Preferably, the material is heated in the compacting step, generally to a temperature of 70 °C or more, up to about 150 °C or less, but preferably 90 °C to 110 °C. The use of this temperature allows for fast compacting. Higher temperatures would be possible, but are less attractive from economic point of view. Heating can be suitably done, via the addition of steam (direct heating), indirect heating via heated coils and/or jacket, or via any other method. The heating step can be done at atmospheric pressure, or under pressure of about 0.1 barg or more up to 3 barg but preferably below 0.5 barg if desired. Working at such slightly increased pressure increases the speed of this step, but is not necessary. Heating can start at any time in the sequence, including before the material is charged to the vessel. In that case, preferably indirect heating is used. In case steam is used to heat the material, it is preferred to start the addition of substantial amounts of steam only after closing of the door. A closed door is also preferred in case the precompacting step is performed at about atmospheric pressure, because the gas stream emitted during the heating step can be easily captured, for example in a scrubber. However, at atmospheric pressure the door may also be a closed extraction hood or the like. In contrast, with an open door, all the emitted gas (comprising steam and VOC's) is emitted in the atmosphere. Capturing this would require a large suction hood, which requires additional investments. Closing the vessel with the autoclave door is preferred, as that does not necessitate any further investment.

The material inside the vessel preferably is agitated by rotation of the vessel, intermittently if required, as soon as loading has commenced. It is also possible to mix the content with a stirrer.

Optionally, if the vessel can be tipped along its axis, (for example, but not limited to +60° to -20° about the horizontal) it may be tipped to an incline or decline to an optimum position for this part of the process at any stage, but usually after loading has finished. Such a position may distribute the material uniformly or concentrate it in one place or position it closer or further away from a steam or other inlet, or position it for some other purpose. A man skilled in the art will be able to find the optimal angle, which may be the same as the loading angle, or different.

The vessel is held, usually while rotation and agitation is progressing, for between 1 and 45 minutes, more preferably between 3 and 15 minutes and most preferably about 5 min or more at elevated temperature. However, the required time for the heating step will be different, depending on the size and efficiency of the heat transfer to the content of the vessel. For example, if only indirect heating is used, the heating time is longer. If direct heating with steam is used, the required time will be dependent for example on the size of the steam lines, and the capacity of the boiler and/or accumulator. The time needed for an efficient downsizing (or compacting) of the waste can be relatively short. By using such short time, the average capacity of a plant can be increased without investment in hardware, and without causing more wastewater to be produced.

If elevated pressure is used during the compacting stage, the vessel is depressurised and may be cooled before the door is opened. It is also possible to apply vacuum to capture even more VOC material, but this is not necessary: the content of the vessel is not very hot, and still relatively dry, so a relatively low amount of vapour is produced when opening the door. These vapours can be captured by a ventilation hood.

The originally fed material has now been pre-heated and compacted. It has been shown, that normal MSW can be significantly compacted, generally about 20 vol% or more, preferably about 25% or more. The compacting is dependent on the type of waste, and medical waste can sometimes be compacted up to 50% as that has more void volume. On average, the compaction was about 30%.

When the precompacting step is finished, and for example, the door is opened, a further amount of waste can be supplied, like for example about 5 volume% or more, preferably about 20 volume% or more, more preferably about 30 volume% or more. Preferably, the vessel is filled till about 95 volume% full.

The further charge(s) of waste may be the same, or different. A different type of waste may be useful, for example when a part needs to be recycled, or when very difficult to treat waste is used. By using the additional volume, the further supplied waste is for example not more than 30% of the total volume.

Generally, after the first additional supply step, it is economically feasible to start the total treatment cycle. However, it may be useful to have another compacting cycle before initiating the full treatment cycle. If the waste can be compacted 50%, it is economically very useful to de two or maybe even three compaction cycles. The vessel is again closed and the above described steps are then repeated one or more times.

Without a pre-shredding step, compacting step or high speed rotation during loading, it is – even with a tilted vessel and without bridging calculated – not possible to reach a filling level of more than 0.35 times the volume in weight. Thus, a 60 m^3 vessel on average can be filled with about 21 tonnes of MSW if loaded at an angle of 45°. In case a horizontal vessel is used, the filling was less than 0.2 times the volume. With the pre-shredding step the vessel can be filled till about 0.4 (0.38-0.45) times the volume in weight; or an increase of about 10% or more up to about 25% increase (hence, 60 m^3 vessel can hold 23-27 tonnes of MSW). With compacting steps, a 0.5 times the volume in weight can be reached (thus, a 60 m^3 vessel may contain about up to 30 tonnes of MSW); however, this can be time consuming. A fill of 0.4 times the volume however (in this example at least 24 tonnes, and representing a 14% or more increase), can be easily reached. Combining shredding and one-step pre-compacting can at least reach 0.45 times the volume in weight (a 60 m^3 vessel contains 27 tonnes of MSW; representing an increase of about more than 25%). Increasing the speed of rotation – apart from the shorter time needed to fill the vessel (depending on the capacity of the hopper and conveyers) – could achieve an increase of about 5 wt% or more, preferably about 10 wt% or more. The inventors have found that having 10-50% more waste in a vessel appeared to increase utilities less than 5-10%; hence, it appeared very favourable to increase the vessel loading.

In one embodiment of the invention, when sufficient pre-heating and compaction cycles have taken place the main cooking or treatment cycle, for example as described in the prior art, is initiated

In the main treatment cycle, preferably, the vessel is first drawn vacuum till about -0.5 to -0.9 barg, and steam is introduced. It may be useful to use indirect heating in stead or in combination with steam supply. The content of the vessel is agitated, preferably by rotating the vessel while applying heat to the contents of vessel via one of the methods above, to change the properties of the contents. The content generally is sterilized and cleaned. Wood and fibrous material are broken down to fibers; plastic is partly softened and balled, adhesives are broken down, such that a treated waste can be obtained that is relatively clean and easy to handle.

After treatment, the vessel is cooled and/or depressurised. Preferably, vacuum is drawn in the vessel, so relatively dry fibres are obtained.

The fully treated waste can be discharged. In case a tiltable vessel with one door is used, the vessel is tilted preferably to about -20° or lower. However, the method is also suitable in autoclaves with two doors and/or with fixed autoclaves.

Generally, the waste is further classified over screens, picking line, eddy current and magnet, destoner and/or other apparatus. Generally, several useful fractions are obtained from the treated waste. Examples of such fractions include, but are not limited to, a fibrous fraction, shattered glass and grit, and larger parts such as plastics (like PET bottles) and metals.

The fibrous fraction as obtained from a first screen may consist for more than 70% of organic material, and may be further purified in organic materials, and can be used as composting additive; fuel or otherwise.

The above description has been focussed on the treatment of municipal solid waste, but the process is equally applicable to other processes where compactable material is treated under elevated pressure and temperature. The process is in particular suitable for treatment of medical waste, because medical waste is often delivered in containers with relatively large free space. Yet, the pretreatment, in particular when using vacuum before and after compacting, precludes dangerous materials to come into the environment. With medical waste it may be useful to heat the waste to e.g. 140 °C in the pretreatment for safety purposes. Yet, the pretreatment can be much shorter than a full cycle, and a very useful increase in capacity can be obtained without any investment. It should be noted that it is not uncommon to comminute the medical waste before loading the vessel. This has however as large disadvantage that the comminuting has to be done in a chamber that is isolated and can be sterilized. Also, such shredding to small particles would lead to exposure of heavy metal contaminants if such step would be applied to MSW.

Other types of compactable materials are waste from slaughterhouses, supermarkets, and waste from landfills that need to be sanitized.

The invention will be elucidated by the following examples, without being limited thereto.

Example 1 and comparative experiments A and B

A 60 m^3 vessel was charged with MSW, which was shredded in a slow rotating single shaft shredder to 20 cm in one dimension. The vessel was at an angle of 35°, and could be filled on a regular basis without problems for over 90 volume% (i.e., more than 54 m^3 in volume). The amount in weight was about 21 tonnes (the average density was slightly under 0.4 after shredding).

In comparative experiments, the following results were obtained: (A) In case the vessel was kept horizontal, the filling percentage was about 30 volume% (and only 5 tonnes by weight MSW by weight was charged). (B) if MSW was charged at an angle of 35°, the best charge was about 90%. However, regularly, bridging occurred (even though the opening in the vessel was more than twice the size in diameter of standard black-bag waste). Due to bridging, the average amount of waste treated was about 85 volume% (16 tonnes of MSW).

Example 2 and comparative experiment C

In October 2008 at the Sterecycle plant at Sheffield Road, Rotherham UK, the following results comparing a standard treatment cycle with an improved cycle using the compactation method were obtained.

Date	Process Description	Total amount processed	Total cycle time
15-27 Oct 2008	**Comparative experiment C (as described in US5540391)** **Standard cycle:** open door of vessel at loading position; start rotation; charge 18t waste; close door and lower to horizontal; apply vac to -0.7 bar; apply steam to 145 ºC; hold while rotating at temp for 60 minutes; vent and apply a vac to -0.7 barg; break vacuum, open door; discharge vessel; return to loading position	18t (yielding 9.9t fibre product)	310 minutes
27-30 Oct 2008	**Example 2 according the invention** **Improved cycle:** open door of vessel at loading position; start rotation; charge 18t waste; close door and lower to horizontal; apply vac to -0.7 barg; apply steam to 101 ºC; hold while rotating at temp for 5 minutes; release pressure; return to loading position; open door; charge further 7t waste; close door and lower to horizontal; apply vac to -0.7 barg; apply steam to 145 ºC; hold while rotating at temp for 60 minutes; apply vac to -0.7 barg; open door; discharge vessel; return to loading position	25t (yielding 14.5 t fibre product)	340 minutes

From the experiments, it appears that the time necessary to treat one tonne of waste is decreased from 17.2 min/tonne of waste to 13.6 min/tonne. In this way, in an increase of capacity of the plant is obtained of more than 20 percent.

Claims

1. Process to treat materials in a vessel at elevated temperature and pressure comprising the following steps: (a) treating household or commercial waste such that substantially all waste has been reduced to a size of about 30 cm or less in at least one dimension wherein the size reduction is not smaller than to 10 cm in at least one dimension, and (b) feeding the treated waste into an vessel till at least 70 vol% full, which vessel is tilted between 10° and 60° from the horizontal, (c) after filling the vessel, the material is subjected to the main cooking or steam treatment cycle, and (d) the treated material from the vessel is obtained, which treated material preferably is classified into one or more useful fractions.

2. Process according to claim 1, wherein the treatment of waste to achieve the required size is performed with a slow-rotating milling apparatus.

3. Process according to any one of claims 1-2, wherein the vessel is filled to more than 0.35 times the volume of said vessel, in weight of MSW.

4. Process to treat materials in a vessel at elevated temperature and pressure, wherein the vessel is loaded with compactable material to be treated, and wherein the material is subjected to at least one compacting stage, the compacting step being performed for some time and at an elevated temperature to have the material reduced in volume, and at least one additional filling step, the material after the compacting and additional filling step(s) is subjected to the main cooking or treatment cycle, and the treated material from the vessel is obtained, which treated material preferably is classified into one or more useful fractions.

5. Process according to claim 4, wherein the compacting stage is performed with the vessel closed.

6. Process according to any one of claims 4-5, wherein the compacting step is performed for sufficient time and at a sufficient temperature to have the material reduced with at least about 10 vol%, after which step the additional material occupies at least 5 vol%.

7. Process to treat materials in a vessel at elevated temperature and pressure, wherein

the vessel is loaded with compactable material to be treated while the vessel having helical flights and the vessel is rotated at speed of 4-10 rpm.

8. Process according to any one of claims 1-3, combined with the process of claims 4-7 and/or with claim 7; or a process according to any one of claims 4-7 combined with the process of claims 1-3 and/or claim 7; or the process according claim 7, combined with the process according to any one of claims 1-3 and/or claims 4-6.

9. Process according to any one of the preceding claims, wherein the process to treat materials in a vessel at elevated temperature and pressure comprises the following steps:

(1) the vessel is loaded with compactable material to be treated to at least 50% full but preferably at least 75% and even more preferably at least about 95% full;

the process further comprises as compacting and additional filling step that:

(2) the material is heated via the addition of steam, indirect heating or via another method, generally to a temperature of 70 °C to 150 °C but more preferably 95 °C to 110 °C,

(3) the vessel is held, usually while rotation and agitation is progressing, for between 1 and 45 minutes, more preferably between 3 and 15 minutes and most preferably about 5 min or more at elevated temperature;

(4) and at least about 5% of further material (preferably about 20% or more, preferably about 30% or more), which may be different to the first if desired, is further loaded into the vessel

(5) optionally, steps 2 to 4 are repeated one or more times; after which step(s),

the material after the compacting and additional filling step(s)

(6) is subjected to the main cooking or treatment cycle,

(7) and the treated material from the vessel is obtained,

(8) which treated material preferably is classified into one or more useful fractions.

10. Process according to any one of the preceding claims, wherein the material inside the vessel is agitated by rotation of the vessel, intermittently if required, as soon as loading has commenced

11. Process according to any one of the preceding claims, wherein the vessel is inclined to be loaded, at about 10° or higher, up to 60° but more usually up to about

45° or higher with respect to the horizontal.

12. Process according to any one of the preceding claims, wherein the compacting step is performed under pressure of 0.1 barg or more, and up to 3barg but preferably of below 0.5barg.

13. Process according to any one of the preceding claims, wherein a vacuum up to -0.9 barg is applied between steps after loading of the vessel.

14. Process according to any one of the preceding claims, wherein heating is started at any time before or during loading of the vessel, or after closing of the vessel.

15. Process according to any one of the preceding claims, wherein in case steam is used to heat the material, the addition of substantial amounts of steam is started after closing of the door.

16. Process according to any one of the preceding claims, wherein the vessel is tipped along its axis in the art usually but not limited to +60° to -20° with respect to the horizontal during the compacting stage.

17. MSW treatment system comprising at least one rotatable and tiltable vessel of a size N m^3, the vessel being at least 50 m^3 in size (hence, N is at least 50), wherein the vessel is resting on bearings, the bearings are able to withstand loading of more than 0.4*N tonnes

18. MSW treatment system according to claim 15, wherein the bearings are able to withstand a load of more than 0.45*N tonnes.

19. MSW treatment system according to claim 16, wherein the bearings are able to withstand a load of more than 0.5*N tonnes.

20. System for treating MSW or commercial waste comprising a feeding section for feeding waste to an autoclave, an autoclave treatment section for treating waste at elevated pressure and temperature over 110 °C, and a classification section wherein the feeding section comprises a slow rotating shredding apparatus which is able to

shred waste till a size of lower than 30 cm in one dimension, but no lower than 10 cm in one dimension