Title: METHOD AND APPARATUS FOR PROCESSING SOLID ORGANIC WASTE

(57) Abstract: In order to provide a method and apparatus for processing solid organic waste to produce a fuel or organic compost, the waste material is treated in a rotary anaerobic digester (116), where it is digested in the thermophilic phase at a temperature in the range 60 - 75 °C, to produce a treated material having a moisture level not exceeding 45 % by weight and preferably not exceeding 35 % by weight. The treated material can be subsequently dried on a drying floor (123) to provide a stable product. Waste having a high moisture level, such as domestic waste can be blended in a blender (115) with waste having a lower moisture level, such as commercial waste, to provide control of the properties of the waste being treated and of the product obtained. The treated solid organic waste from the anaerobic digester may also be pyrolysed and, optionally, subsequently gasified.
METHODS AND APPARATUS FOR PROCESSING SOLID ORGANIC WASTE

The present invention relates to methods and apparatus for processing solid organic waste, for example municipal waste or agricultural waste. The waste may be processed to provide fuel or a multi purpose pure organic compost.

The disposal of municipal and agricultural waste presently provides a major problem. A medium sized city may produce in the region of hundreds of thousands of tonnes of waste a year. Whereas in the past it has been the practice to dump this waste in landfill sites, this is becoming less favoured, as the availability of suitable sites for landfill is decreasing.

At the same time, there is concern over the rate of consumption of fossil fuels. These fuels are not replaceable and in some cases present pollution problems due to a high sulphur content. There is a corresponding interest in finding a source of low pollution fuel which does not deplete fossil fuel stocks.

There is a wide interest in the use of organic material as compost for horticultural purposes. In the past, materials such as coir have been used, which has a relatively low nutrient content. Peat has also been used, but there is now concern that natural peat bogs are being dangerously depleted by this use.

Accordingly, there is an interest in recycling municipal and agricultural waste to produce either a fuel material for replacement of fossil fuels or organic compost for horticultural purposes. A number of processes have been proposed in which agricultural or municipal waste is composted in a specially design apparatus so that it is treated by aerobic digestion. Examples of each process are described for example in GB1551020 and WO83/02779. Although these can be effective, there is a problem that the aerobic digestion can lead to loss of carbon content and consequently lowering of calorific value of the resulting material. Further processes have been proposed in which
waste is subjected in a first step to aerobic digestion and subsequently to anaerobic digestion to improve the quality of the product, for example as in GB2208645. Aerobic digestion has also been found to require long digestion times, sometimes of the order of weeks.

Where an anaerobic digestion process has been used, it has taken place in large static tanks which has given rise to problems of disposal of leachate and a relatively large hold up volume requiring specially constructed tanks.

Further, in all processes in which organic waste is digested aerobically or anaerobically, a drying step has been required to reduce the moisture level to below 30% by weight. Once the moisture level has been reduced to this level, further bacterial activity ceases so that the product becomes stable and can be stored. However, the drying step has typically required heated or forced draught-drying apparatus which has been expensive to run.

The present inventor has set out to overcome the problems of the prior art. The present inventor has particularly sought to provide a method of processing organic waste in which an expensive drying apparatus is not required. The inventor has further set out to provide a process and apparatus for processing municipal waste which has a very variable moisture level and physical composition, so that a relatively homogeneous product can be produced.

An alternative approach to the disposal of waste uses incineration, in which the waste is heated to a very high temperature to oxidise it. However, the plant required for the incineration is complex and expensive. There are problems in the operation of the plant due to the uneven nature of the waste being collected and the high moisture content which is often encountered. There can be problems with generation of pollutants particularly NOx.

For this reason, an alternative method of thermal decomposition of waste involves a pyrolysis step, in which the waste material is heated to a temperature of about 800°C, whereby a mixture of combustible gases is produced and the solid material is reduced to
a largely carbonaceous char. The char can be subsequently gasified either insitu or in a separate step, for example using steam, to generate further combustible gases. The combustible gases from the pyrolysis and gasification process can be burnt at high temperature under controlled conditions for production of heat. This heat can be used to provide power and to run the process. Generation of pollutants is effectively controlled because the degradation of the waste occurs at a temperature below that at which NO\textsubscript{x} gases are produced and the combustion of the gases can be conducted under controlled conditions which reduce the generation of such gases. However, there are problems with the control of such processes where the composition and water content of the waste being processed are not uniform from time to time. A drying step can be used, but this adds complexity.

The present inventor has discovered that solid organic waste can be treated by anaerobic digestion whilst being agitated, to provide a good quality raw material which is suitable for subsequent processing to provide a fuel or compost product and which has an average moisture level not exceeding 45% by weight and preferably not exceeding 35% by weight. Subsequent drying of this material to an average moisture content of below 30% by weight can be carried out relatively easily. It is found that both the calorific value and the nutrient content of waste treated in this way remains high so that it is suitable as a replacement fuel or compost.

Accordingly, in a first aspect, the present invention provides a method of treating solid organic waste, comprising treating the waste by anaerobic digestion, the solid waste being agitated during digestion, the waste having an average moisture level after treatment not exceeding 45% by weight and preferably not exceeding 35% by weight.

The inventor has also discovered that the input of solid organic waste can be controlled so that a relatively homogeneous product with a moisture level not exceeding 45% by weight, and preferably not exceeding 35% by weight, can be obtained.

Accordingly, in a first aspect, the present invention also provides an apparatus for treating solid organic waste, comprising an anaerobic digestion vessel, means for agitating the solid organic waste in the vessel, and drying means following the digestion
vessel and means for controlling the input of solid organic waste to the vessel so that moisture level of waste after treatment does not exceed 45% by weight and preferably does not exceed 35% by weight.

In a particularly preferred embodiment, the input of waste is controlled by mixing solid organic waste with a controlled amount of other waste, for example commercial waste, which has a moisture level not exceeding 30% by weight. In this way, variations in the physical composition (for example calorific content) and moisture level of the solid organic waste (typically domestic waste, but also possibly agricultural waste) can be smoothed out, so that a product formed from treated waste from different areas or different time periods can be relatively homogeneous. For a fuel, homogeneity is required in parameters such as ash content, calorific value, moisture level and density. For an organic compost, homogeneity in parameters such as moisture level, density and nutrient content is required.

Preferred features of the first aspect of the invention will be described further below.

The term 'digestion' is used herein to indicate the bacterial breakdown of at least some of the organic matter to produce heat. This breakdown is accompanied by changes in the physical nature of the waste.

The substantially anaerobic digestion process should be carried out using the thermophyllic phase, which normally occurs in the temperature range 60°C – 75°C, most preferably around 63°C – 70°C. In this phase, very rapid digestion occurs with the production of heat. It is found that the reaction in the thermophyllic phase is much quicker than the commonly used mesophyllic phase which occurs in the range 30°C – 38°C. Accordingly, rapid treatment of the waste can take place. However, if the temperature rises above 75°C, there is a danger that the bacteria will be destroyed.

The reaction in the thermophyllic phase results in the natural generation of heat which breaks down the solid organic waste to produce a material which is suitable for processing to provide a fuel or compost. The reaction will almost always provide sufficient heat to maintain itself without provision of supplementary heat.
In order to allow the anaerobic digestion to take place, the material may be placed in a sealed container with no supply of additional air during the reaction.

According to the first aspect of the invention, the waste should be agitated while it is being digested. Agitation may take place by any suitable means, but it is particularly preferred that the digestion takes place in a rotating anaerobic drum.

The drum may be rotated at any suitable rate, and suitably completes one revolution in a time range of 1 minute to 10 minutes, preferably 2-5 minutes, most preferably about 3 minutes.

The drum preferably comprises a substantially parallel sided circular section cylinder. The axis of the cylinder may be inclined to the horizontal, for example at an angle in the range 3° – 10° most preferably 5° – 8°, to provide gravitational flow through the drum.

Any suitable size of drum may be provided, depending upon the rate of consumption of organic waste. It has been found that, for a processing rate of about 250-500 tonnes per day, a drum of diameter in the range 3.5 – 8m, preferably 4-6m most preferably around 5.5m should be used. The length should be in the range from 4 to 8 times the diameter, most preferably about 6 times the diameter.

The drum may be used of any suitable material, for example steel.

A rotary digester has the advantage that it is mechanically simple. There are relatively few problems of blocking and very few moving parts, which reduces the risk of breakdown.

The agitation caused by the rotation leads to attrition of the solid waste, further contributing to its breakdown. Preferably, the drum is substantially completely filled with waste, being preferably at least 75% full by volume. This leads to increased attrition, rapid heat generation and also to efficient use of plant.
Residence time in the anaerobic digestion process is suitably in the range 18-60 hours, more preferably around 24 to 48 hours, most preferably around 36 hours.

During processing, it is found that the volume of the material may decrease by as much as 25%. The gas space over the material will accordingly increase. The gas space will comprise air and carbon dioxide, and is saturated with water vapour.

Aerobic digestion does also occur at a low level in early stages in the process. The rate of aerobic digestion increases at later stages in the process when the material is less dense and less moist. The waste material should be discharged from the anaerobic digester at a stage at which the treated waste material is sufficiently digested and sufficiently dry. This typically occurs after a period of about 48 hours. By restricting residence time to 48 hours or less, additional loss of carbon can be reduced.

In order to promote the anaerobic digestion process, some parameters of the solid organic waste fed to the digestion step are preferably controlled.

In the first place, the solid organic waste is preferably treated in a first process before anaerobic digestion to remove particles of size in excess of 60mm, more preferably 50mm. This process may comprise a first step in which very large objects are removed, for example by hand and a second step in which the remaining material is treated to reduce its particle size, for example by shredding. The person skilled in the art will be able to obtain suitable shredding apparatus.

The second parameter which may be controlled is the moisture content of at least some of the organic solid waste fed to the anaerobic digestion step. The moisture level of this part of the waste is suitably in the range 40-75%, more preferably 60-70%, most preferably around 60% by weight. Waste having a moisture level in the range 50-80%, preferably in the range 65%-75% by weight can also be used

All moisture levels quoted herein are % by weight. They are average values, being averaged for quantities of at least 100kg of waste. Moisture levels of solid waste may be measured by measuring the moisture level of air or gas over the waste at a fixed temperature and in equilibrium with it.
As will be described further below, waste having a moisture level in the range in the range 40-75% by weight may be mixed with waste having a lower moisture level, but it has been found that the anaerobic digestion process will proceed effectively, if sufficient waste having the higher moisture level is present. It has been found to be acceptable if the average moisture level of all waste fed into the digestion step is in the range 50-60% by weight and preferably 53-57% by weight.

Alternatively, if the delivered waste is low in organic content so that the moisture level is not sufficient to support anaerobic digestion, process water is preferably added. This process water is preferably waste water from water treatment, most preferably dewatered sewage sludge. This material has a high nitrogen content and acts as a catalyst for the anaerobic reaction.

As mentioned above, it is particularly preferred feature of the first aspect of the present invention that control of the moisture level can be obtained by blending solid organic waste with other waste of a lower average moisture level. It is found that domestic waste typically has a moisture level in excess of 60% by weight. Agricultural waste may have a moisture level in excess of 75% by weight and sometimes 80% by weight, particularly in tropical or sub-tropical countries for crops such as bananas and pineapples. Finally, commercial waste from offices and factories is typically much drier, having a moisture level in the range 20% – 30% by weight.

The moisture level of waste fed to the digester may be manipulated by altering the mixing ratios of different types of waste. It is required that at least part of the waste fed to the digester has a moisture level in the range 50% – 80% by weight, preferably 50-75% by weight in order to promote the faster thermophilic reaction. However, part of the waste fed to the digester may comprise a relatively dry commercial waste. The heat generated by the digestion of the moist waste is sufficient to treat the whole of the waste fed to the digester. However, during the agitation process, the commercial and domestic waste are slowly mixed together reducing the overall moisture content of the mixture,
so that at the end of the processing, the moisture level does not exceed 45% by weight and preferably does not exceed 35% by weight.

Solid waste with higher moisture level may be blended with solid waste with lower moisture level in blending apparatus in a controlled manner. The relative quantities of different types of waste can be controlled so that the desired average moisture level is obtained as explained above.

The blending step also allows absorbent material such as paper and paper based material (which is particularly common in commercial waste) to be blended intimately with the moist waste (such as domestic waste). The absorbent material absorbs liquid rich in bacteria, providing a substrate for the bacteria to grow on and allowing the bacteria to be spread throughout the waste being processed. This promotes reaction and mixing, leading to an improved digestion. Further, the wetting of the paper helps it to be broken down.

In processing solid organic waste it is particularly important to produce a product which is substantially homogeneous, at least at the scale of mm or above. The blending step helps to improve the homogeneity of the product.

However, although blending takes place, it is found that the moisture level remains concentrated in local areas of the waste, where it is sufficiently high to allow the thermophilic reaction to commence and proceed very rapidly.

The relative quantities of different types of waste fed can be controlled using automatic weigh feeders.

A further parameter which may be manipulated is the pH of the organic waste. This is suitably in the range 6.0-8.5, preferably 6.3-7.3, most preferably around 6.8.

It has been further found that the density of the organic waste fed to the anaerobic digestion process is suitably not too low. Preferably, the density is not less than 450g per litre, preferably not less than 750g per litre. Again, the blending step is
particularly useful here. Domestic waste can have a relatively high density. The average density can be controlled by admixing a suitable quantity of commercial waste, which has a comparatively low density.

**Preliminary Treatment**
As described above, the solid organic waste may be subjected to various types of treatment before the anaerobic digestion process. Preferably, the previous steps include any or all of the following:

1. **Picking**
Initial treatment to remove objects which are not combustible, such as stone, concrete, metal, old tyres etc. Objects having a size in excess of 100mm or more may also be removed. The process can be carried out on a stationary surface, such as a picking floor. Alternatively or additionally, the solid organic waste may be loaded onto a moving surface such as a conveyor and passed through a picking station in which mechanical or manual picking of the material takes place.

2. **Screening**
The organic solid waste may be mechanically screened to select particles with size in a given range. The given range may be from 10mm to 50mm. Material less than 10mm in size comprises dust, dirt and stones and is rejected. The solid organic waste may be treated to at least two screening processes in succession, each removing progressively smaller fractions of particles. Material removed in the screening process as being too large may be shredded to reduce its average size. Material which is classified by the screen as being of acceptable size and, where applicable, shredded material can then be fed to the anaerobic digestion step.

3. **Blending**
Domestic and commercial waste may be blended in a blending mixer before being fed to the anaerobic digestion process.
This is particularly important step. Where least domestic waste and commercial waste are received for treatment, they are preferably processed separately. It is found that commercial waste can be treated before the anaerobic digestion process in a picking stage to remove oversized objects followed by a shredding stage only. By keeping the different types of waste separate, accurate control of quality of solid waste fed to the anaerobic digestion step can be obtained.

Subsequent Treatment
The treated material may be subjected to a number of steps after the anaerobic digestion process. These steps may include any of the following:

1. **Grading**
The material may be screened to remove particles in excess of a given size. For example, particles in excess of 50mm may be rejected. They may be subsequently shredded to reduce their size, returned to the anaerobic digester or simply rejected.

2. **Metal Separation**
Relatively small metal particles such as iron or aluminium may have passed through the system. They can be removed, for example by a magnetic or electromagnetic remover in a subsequent step. Metal particles removed from the system may then pass to a suitable recycling process.

3. **Drying**
Suitably, after treatment in the anaerobic digestion process, the material is subjected to a drying step. However, with the first aspect of the present invention, because the moisture level does not exceed 45% by weight, preferably not exceeding 35% by weight, after the digestion step, the subsequent drying can be carried out relatively simply.

For example, in a first stage, a forced draught of air may be provided during or after the unloading phase from the anaerobic digestion process. During this stage, the treated material will still be at high temperature (for example in the range 50-60°C) and a lot of moisture can be removed simply by forcing air over it.
A further drying step may comprise laying the material out on a drying floor. In this step, material is laid out at a thickness of not more than 20cm over a relatively large area for a suitable period of time, during which the moisture level drops. The material may be agitated, for example by turning using mechanical or manual apparatus such as a power shovel. The material may be turned at intervals of for example of 2-4 hours preferably around 3 hours. Preferably, during this stage, the moisture level drops to below 30% by weight after which no further biological decomposition occurs. Suitably, the material is left on a drying floor for a period in the range 18-48 hours, preferably 24-36 hours, more preferably around 24 hours.

It is also found that further drying may take place during subsequent processing, due to the mechanical input of energy.

Waste heat from other process equipment, for example from furnaces, may be used to dry the material.

4. **Pelletising**

In order to convert the treated material to fuel, the material may be classified according to size and subsequently densified to provide pellets of suitable size which can be subsequently stored or packed for use. During this stage, further drying of the material may occur, due to heat generation caused by friction and due to further exposure to air. Preferably, in order for pelletising to proceed well, the moisture level of the treated material is in the range 33-38% by weight.

5. **Bagging**

Where the material is to be converted into compost, it can simply be bagged after treatment.

By way of example, the moisture level of solid, organic waste during processing may be as follows.
Domestic waste with a high organic content and moisture level above 60% can be mixed with commercial waste having a moisture level of 20% or below in a suitable ratio to provide a blend having an average moisture level in the range 50-60% by weight.

During anaerobic digestion, a part of the moisture is absorbed by the gas and air above the material being processed. The average moisture level may drop to around 45-50% by weight, preferably 35-40% by weight.

During emptying of the digester, the waste which still has a high residual heat level, may be dried by a forced draught as described above, so that the moisture level drops to the range 40-45% by weight, preferably 35-40% by weight.

The waste may then be further dried on a drying floor as described above, so that the moisture level drops to below 30% by weight.

It has been found that the process of the first aspect of the present invention for treating domestic waste can allow up to 85% by weight of delivered waste to be recycled. The remaining 15% by weight has to be rejected and disposed of by conventional means.

Further use of treated material

The method and apparatus of the invention can be used to produce a product which is suitable for subsequent storage, transportation or sale.

It has been found that the method of the invention can provide a fuel, referred to as Green Coal, which has a calorific value in the order of 3500 Kcals/g which is about half that of industrial coal. The material has an ash content of less than 20% by weight and has the additional advantage that it will contain relatively low levels of sulphur and chlorine, so reducing pollution due to acid rain from gases of combustion.

By blending different sources of waste material, fuel produced at different times or with waste from different locations can be relatively homogeneous in terms of:
1. Calorific value - suitably in the range 3000-4000 Kcal/g,
2. Density – suitably in the range 270-350g/l more preferably around 300g/l
3. Moisture level – below 30% by weight and preferably around 20% by weight.

This fuel can be used either on its own or as a supplementary fuel.

Alternatively, the material can be used as a multi purpose organic compost having a relatively high nutrient content.

The apparatus and method of the invention may alternatively form a part of a plant or system. The apparatus and method of the invention can be used to supply fuel in a plant or system. For example, the material may be fed directly to a combustion chamber for generating heat or power. The apparatus and method of the invention can be used to supply a feed to a pyrolysis process, as described below.

The treated material may be fed directly from the digestion vessel to the plant or system or it may be treated by any suitable steps such as grading, metal separation, drying, palletising or bagging as appropriate.

In a particularly preferred embodiment, there is provided an electrical power supply system comprising apparatus according to the invention for feeding material to the combustion chamber of a boiler for providing steam for power plant. In an alternative embodiment, there is provided a cement producing apparatus comprising a cement kiln and an apparatus according to the invention for supplying fuel to the cement kiln.

In this embodiment, complete heat transfer from the fuel to the cement producing materials is obtained as they are mixed together in the kiln. The ash from burning the material of the present invention, is absorbed into the cement material. Waste heat from the kiln can be used to dry the treated waste from the present invention or to provide power for operating the process.
The present inventor has further realised that solid organic waste fed to a pyrolysis process can be initially treated by a digestion step, to make the solid organic waste more uniform and more suitable for use in the pyrolysis process. Accordingly, in a second aspect, the present invention provides a method of treating solid organic waste, comprising treating the waste by bacteriological digestion and subsequently subjecting the waste to heating at a temperature which is sufficiently high to substantially pyrolyse the digested waste anaerobically.

The pyrolysed material may be used as a fuel in its own right. However, in a preferred embodiment, the pyrolysed material may be fed to a gasification process in which combustible gases are produced by introduction of a gasifying agent. This will normally require the pyrolysed material to be at a high temperature and the gasification process preferably occurs directly after the pyrolysis process.

The pyrolysis process and gasification process may be carried out in separate zones, for example as described in WO97/15641 and WO97/15640, or in a common zone, for example as shown in GB2301659.

Suitably, the gasifying agent comprises air, steam or water vapour.

Preferred methods and apparatus for the pyrolysis and gasification processes are disclosed in GB2301659, WO97/15640, WO97/15641 and WO01/96501.

Suitable apparatus may also be obtained from Metso Corporation, or from the Allis Chalmers Corporation.

The bacteriological digestion may be aerobic or anaerobic. Preferably, it is anaerobic.

Suitably, it is carried out using the thermophyllic phase, which normally occurs in the temperature range 60°C – 75°C as described above in relation to the first aspect of the invention. Suitably, the digestion takes place in a sealed container, for example a rotating drum. Preferred aspects of the drum are as set out above for the first aspect of the invention.
Preferably, the solid organic waste is digested in a manner which allows its moisture level to be controlled.

It is particularly preferred that the solid organic waste is digested by a method according to the first aspect of the invention. Suitably, an apparatus according to the first aspect of the invention is used. The preferred features of the first aspect of the invention described above apply to the second aspect of the invention.

However, instead of the optional treatments of grading, metal separation, drying, pelletising and bagging described above subsequent to the anaerobic digestion process, the treated material from the anaerobic digestion process is suitably fed directly to the apparatus for pyrolysis. Any suitable feed means may be used for delivering the treated waste from the anaerobic digestion process to the pyrolysis apparatus.

As the anaerobic digestion process is typically carried out in a batch wise fashion, whereas the pyrolysis process typically requires a continuous feed of material, an interim storage means, for example in the form of a feed hopper may be provided. It is preferred that there is a first delivery means for receiving treated organic waste from the anaerobic digestion process and feeding it into the interim storage means and a second feed apparatus for feeding the stored treated solid waste from the interim storage means to the pyrolysis apparatus. The second feed means is preferably operated substantially continuously. The first and second feed apparatus may comprise any suitable means, for example conveyor belts or screw feeders.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a schematic process diagram of steps involved in the process of the present invention before the rotary anaerobic digester.

Figure 2 is a schematic process diagram showing the steps involved in feeding the rotary anaerobic digester and drying the material.
Figure 3 is a schematic process diagram showing further steps in the procedure.

Figure 4 is a schematic process diagram showing a further embodiment of the present invention.

**DETAILED DESCRIPTION OF THE DRAWINGS**

Figures 1, 2, and 3 from a continuous process diagram which has been divided into three sections for convenience of illustration.

Figure 1 shows the steps involved in an embodiment of a process according to the first aspect of the present invention for manufacturing fuel from solid organic waste. In this embodiment, two sources of waste 101 and 102 are identified. Source 101 comprises a source of domestic waste, which typically has an average moisture in the range 35-60% by weight. Source 102 comprises a source of commercial waste which may have moisture averaging around 20% by weight.

At 103, waste from the sources 101 102 is delivered to a reception and picking floor. On the reception and picking floor, waste supplies from the two sources 101 and 102 are kept separate. On the picking floor, waste is manually picked over to identify objects which are not suitable for further processing, for example, metal, large plastic objects, etc. The rejected objects are collected at 104 and disposed of separately, for example by tipping or by recycling if appropriate.

The dotted line in step 103 indicates separation of the solid waste from the two sources.

On the left hand side of figure 1, domestic waste which has been manually picked over is then fed at 105 onto a feed conveyor 106 using a loading hopper arrangement. Further manual sorting of the solid waste can take place whilst the waste is on the feed conveyor 106 for example by personnel standing on both sides of the conveyor. The rejected waste can be disposed of in step 104 as described above.
The feed conveyor 106 feeds the sorted waste to a rotary screen separator apparatus 107. In a first rotary screen separator 108, particles of size less than 50mm are passed and allowed to fall onto a conveyor 109 for subsequent feeding to the rotary anaerobic digester as will be described further below in figure 2. Material screened out by the rotary screen separator 108 is then screened in a further rotary screen separator 109 which passes objects of size less than 100mm. Objects of size less than 100mm are then fed to a domestic waste shredder 110 which reduces their size to below 50mm and greater than 10mm. Thereafter, the shredded waste is passed onto to the conveyor 109.

Objects of size greater than 100mm are fed onto an “oversize conveyor 112” for further processing.

Returning to the reception floor 103, commercial waste which has been sorted is directed to a commercial waste conveyor 113. Whilst this is on the conveyor, the waste may be subject to further hand picking by personnel located adjacent to the conveyor. Material from the oversize conveyor 112 and commercial waste from the commercial waste conveyor 113 are combined and together fed into a commercial waste shredder 114 of suitable design which shreds the waste so that it has a particle size not greater than 50mm.

In Figure 2, the waste products on the conveyor 109, which will comprise unmixed domestic and commercial waste are blended together in a blender 115. Further, paper and paper based material in the commercial waste absorbs moisture in the domestic waste which is rich in bacteria, thus spreading the bacteria throughout the material and providing a substrate to promote bacterial action.

The blended waste is fed from the mixer 115 intermittently to the anaerobic digester 116. The anaerobic digester comprises a cylindrical steel vessel of diameter 5.5mm and length 33m which is mounted with its axis at an angle of approximately 7° degrees to the horizontal with waste being fed in at the loading end 117. Waste is fed into the loading 117 end at intervals of approximately 24 hours, and is simultaneously discharged.
Except when loading and unloading, the rotary anaerobic digester is sealed to prevent access of air so that conditions may remain substantially anaerobic inside the anaerobic digester. The digester is normally rotated at a rate of approximately one revolution every 3 minutes. During loading and unloading, the rate of rotation is increased to 1 rpm to help feed material down the digester. As a result, the waste inside the rotary anaerobic digester is gently agitated. Also, as the digester is mounted at an angle to the horizontal, the waste slowly feeds downwards from the loading end 117 to the unloading end 118.

During the loading phase, as mentioned above, a mixture of domestic and commercial waste which has been pre-treated is fed from the mixer 115 into the loading end 117 of the rotary anaerobic digester. By controlling the rate of feed of treated domestic waste on the conveyor 109 and treated commercial waste on the conveyor 113, the average moisture level of the solid waste fed into the loading end 117 of the rotary anaerobic digester 116 can be controlled.

The temperature inside the rotary anaerobic digester is maintained at a temperature in the range 65-75°C, most preferably around 68-70°C. Although it is possible to provide auxiliary heating means, this is not normally required, as the moist solid waste fed into the digester undergoes a thermophyllic anaerobic reaction which leads to the generation of sufficient heat to maintain the temperature at the desired level.

It can be seen that the screening and shredding apparatus can be used to ensure that the waste fed into the rotary anaerobic digester does not have a particle size greater than 50mm. Further, by controlling the relative quantities of commercial and domestic waste fed into the rotary anaerobic digester using the blending system, the overall moisture level of at least part of the load can be maintained at the high level leading to a high rate of reaction. Further whilst the waste is on the conveyor or picking floor, it can be tested to ensure that its pH is the correct range and suitable additives can be added to correct the pH in a manner known to the person skilled in the art if necessary. Further, the shredders can be operated to ensure that the density of the waste material does not fall below 750gm per litre.
It has been found that if the solid waste fed into the rotary anaerobic digester meets the following parameters, a high rate of anaerobic digestion can be obtained:

1. less than 50mm in size
2. moisture content between 50 and 70%, ideally 60% by weight.
3. pH between 6.5 and 8.0
4. density not less than 750gm per litre.

The rotary anaerobic digester is operated so that waste has residence time of approximately 24 hours inside the digester. During an appropriate unloading phase, digested waste is unloaded at the unload end 118 where it is sieved. Digested waste with a particle size less than 50mm is collected at 119. This material is suitable for formation of fuel pellets as will be described further below. Treated waste with a particle size in excess of 50mm is collected at 120 and rejected. A grid inside the digester, over the final 1 metre length, for passing objects of size less than 50mm is provided, to reject oversize material.

In step 121, the sieved treated solid waste is treated in a metal separation stage, for separating out metals such as iron and aluminium. In a manner known in the art, electromagnetic or magnetic apparatus can be used to separate various materials which can be collected at 122 for suitable recycling.

The treated waste from which metal has been received can be spread on a stockpile / drying floor 123.

Treated waste collected at the unloading end 118 has a moisture level of not more than 35% by weight and preferably not more than 35% by weight. A certain amount of the moisture in the treated solid waste material goes into the gas over the material in the rotary anaerobic digester. A certain amount of the moisture is driven off for example by a forced draught fan at the unloading stage 118 when the anaerobic digester is opened the waste sieved.

The moisture level of the treated waste loaded onto the drying floor is typically in the range 30-35% by weight and the material will still be at a temperature in the range 50-
60°C from the drum. The material is fed into a layer not more than 20cm thick, where it is allowed to dry by natural evaporative drying and mechanical turning. As a result, the moisture level drops to a level of less than 30% by weight. At this stage, further bacterial decomposition of the material ceases and the product becomes stable and storable.

In Figure 3, dried treated waste from the stock pile 123 is loaded onto a feed conveyor 124 where it is fed to a classifier 125 for separating treated waste which is of too large a diameter. Particles of size in excess of 50mm are rejected and collected at 126. Particles of size less than 50mm are collected in a hopper 127 from whence they are fed to a feed stock transfer conveyor 128 which transfers the treated waste to densifiers 129 and 130. The densifiers compress and pelletise the waste and further reduce the moisture level. Over spill from the conveyor 128 is collected at 132 and returned to the conveyor 134. Pelletised treated waste is collected on a conveyor 131 and delivered to a stockpile or bagging stage at 133.

**EXAMPLE**

A process according to figures 1-3 was operated with a feed a comprising 75000 tons per annum of mixed municipal waste. The average moisture level of waste input to the rotary anaerobic digester was 60% by weight, with some batches having higher moisture level and some batches having lower moisture level.

Treated waste collected from the rotary anaerobic digester, after unloading and fan drying had a moisture level of about 35% by weight.

After 24 hours residence on the drying floor 123, the moisture level had dropped to below 30% by weight and the product was stable.

From an input of 75,000 tonnes of combined waste materials, 50,000 tonnes of GREEN COAL can be produced, having a calorific value equivalent to 25,000 tonnes of fuel oil.
The graded and pelletised product was found to have constant thermal characteristics and to be suitable for use as a supplementary fuel, going by the description of GREEN COAL. It had a minimum calorific value of 3500Kcals/g. It had an ash content of less than 20% by weight and very small quantities of sulphur and chlorine.

Figure 4 shows a schematic process diagram of a second embodiment of the present invention.

The embodiment of Figure 4 will employ the system as shown in Figure 1 for the pre-treatment of solid waste material and digestion in a rotary anaerobic digester 116 as shown in Figure 2. However, the embodiment of Figure 4 is different to that of Figures 2 and 3 in that a different system is employed downstream of the anaerobic digester. At the output end 118 of the rotary anaerobic digester, the treated material is fed into a gravity hopper 118 for storage of material. The stored material is fed from the gravity hopper 134 by a screw feeder 135 into a pyrolysis chamber 136 in which the solid waste material is transported by a screw while being heated to a temperature in excess of 800°C, sufficient to cause pyrolysis of the treated waste material. As a result, a mixture of combustible gases is produced at 139. The solid material is reduced to a char, largely comprising carbon and ash.

The char may, in some embodiments, be used as a fuel. However in the process shown in Figure 4, the char is fed into a gasification chamber 138, where it is maintained at a temperature in excess of 800°C and treated with steam so that a mixture of carbon monoxide and hydrogen are generated at 140. As a result, the char is converted to a non-combustible ash 141 which is subsequently disposed of, suitably by landfill.

The combustible gases from the pyrolysis chamber 139 and the producer gas 140 from the gasification chamber 138 are burnt at high temperature in a combustion chamber 142. As a result, exhaust gas is produced. The exhaust gas has a very low content of pollutants in particular, NOx gases, because of the combustion conditions.

The combustion of the gases 139 and 140 is used to produce steam, some of which is fed at 144 into the gasification chamber and the remainder of which is fed at 143 into a
steam turbine power plant 145 for the generation of electricity. Electricity from the power plant can be distributed at 146 for running the entire apparatus of the embodiment of Figure 4. Power can also be delivered at 147 to consumers, via the National grid for example.

The pyrolysis and gasification apparatus is shown schematically only. It is suitably as described for example in WO97/15640 or WO97/15641. Alternatively, the gasification and pyrolysis chambers may be combined, for example as shown GB2301659.
CLAIMS:

1. A method of treating solid organic waste, comprising treating the waste by anaerobic digestion, the solid waste being agitated during digestion, the waste having an average moisture level after treatment not exceeding 45% by weight and preferably not exceeding 35% by weight.

2. The method of Claim 1, wherein the solid organic waste is treated in a rotary anaerobic digester.

3. The method of Claim 2, wherein the rotary anaerobic digester is rotated at a rate of one revolution in a period ranging from 1 minute to 10 minutes, preferably 2 to 5 minutes.

4. The method of any preceding claim, further comprising the step of mixing the solid organic waste with other solid waste of average moisture level less than 30% by weight before digestion.

5. The method of claim 4, wherein the relative quantities by weight of the solid organic waste and the other waste are controlled.

6. The method of Claim 5, wherein the solid organic waste and the other solid waste are mixed so that the overall average moisture level is in the range 50-60% by weight, preferably 45-60% by weight.

7. The method of any preceding Claim, wherein the treated solid organic waste is processed to form fuel.

8. The method of any of Claims 1 to 6, wherein the treated solid organic waste is processed to form compost.
9. The method of any preceding claim, wherein, before treatment, the solid organic waste has a moisture level in the range 45-75% by weight, more preferably 60-65% by weight, a pH in the range 6.0 to 8.5, a density of not less than 450g/l and a particle size not exceeding 50mm.

10. Apparatus for treating solid organic waste, comprising an anaerobic digestion vessel, means for agitating the solid organic waste in the vessel, and drying means following the digestion vessel and means for controlling the input of solid organic waste to the vessel so that moisture level of waste after treatment does not exceed 45% by weight, preferably not exceeding 35% by weight.

11. Apparatus according to Claim 10, further comprising a supply of solid organic waste and a supply of other waste having an average moisture level of not more than 30% by weight and means for mixing the solid organic waste and the other waste before it is fed to the digestion vessel.

12. Apparatus according to Claim 11, further comprising control means for controlling the relative quantities by weight of the solid organic waste and the other waste mixed together.

13. The method of treating solid organic waste, comprising treating the waste by bacteriological digestion and subsequently treating the treated waste in a pyrolysis process.

14. A method according to Claim 13, wherein after the pyrolysis process, the pyrolysed waste is treated in a gasification process.

15. A method according to claim 13 or 14, wherein the bacteriological treatment is anaerobic digestion.

16. A method according to claim 13, 14 or 15, wherein the solid organic waste is treated by method of any of claims 1, to 6 or 9.
17. Apparatus for treating solid organic waste, comprising a bacteriological
digestion vessel, means for feeding bacteriologically digested solid organic
waste from the bacteriological digestion vessel to means for pyrolysing the
treated solid organic waste.

18. An apparatus according to Claim 17, further comprising means for gasifying
the pyrolysed solid organic waste.

19. An apparatus according to claim 16, wherein the solid organic waste is
treated in an apparatus according to any of claims 10-12.

20. A method of treating solid organic waste, substantially as herein described
with reference to the accompanying drawings.

21. Apparatus for treating solid organic waste substantially as herein described
with reference to the accompanying drawings.
### INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

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According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>US 4 935 035 A (BERGER JOSEF) 19 June 1990 (1990-06-19) claims 1-14; example 1</td>
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**X** Further documents are listed in the continuation of box C. **X** Patent family members are listed in annex.

* Special categories of cited documents:

- **A** document defining the general state of the art which is not considered to be of particular relevance
- **E** earlier document but published on or after the international filing date
- **L** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- **O** document referring to an oral disclosure, use, exhibition or other means
- **P** document published prior to the international filing date but later than the priority date claimed

**"A"** later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

**"X"** document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

**"Y"** document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

**"X"** document member of the same patent family

**Date of the actual completion of the international search**

29 March 2004

**Date of mailing of the international search report**

06/04/2004

Name and mailing address of the SA

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Fax (+31-70) 340-2016

Authorized officer

Glod, G
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<td>WO 01 79123 A (DAUB ROMAN ;HAUTZ AXEL (DE); NUMRICH REINER (DE)) 25 October 2001 (2001-10-25) page 8, line 30 -page 13, line 3; figures 1,2</td>
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Continuation of Box I.2

Claims Nos.: 20, 21

The subject-matter of claims 20 and 21 is defined by reference to the drawings and not by apparatus or method features, respectively. The scope of said claims is therefore completely undefined and no meaningful search can be done for said claims.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.
INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. X Claims Nos.: 20, 21
   because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
   see FURTHER INFORMATION sheet PCT/ISA/210

3. □ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. □ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

□ The additional search fees were accompanied by the applicant's protest.

□ No protest accompanied the payment of additional search fees.
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