

SPECIFICATION

Method for the production of methane and an apparatus in which the method is carried out

The present invention relates to a method for the production of methane from a substrate containing an organic material, by way of example manure, in a process by means of a culture of anaerobic and preferably thermophile microorganisms, and to an apparatus in which such a method is carried out.

Methane (CH_4) is known as a useful source of energy for heating purpose and as fuel for internal combustion engines for driving working machines or for the production of electric power. Methane can be produced by means of anaerobic microorganisms with a biological mass as substrate. Manure from cowsheds or swineries, vegetable or animal waste from farms and food-production industries can be used as biological material for example. Also sewer sludge can be utilized, if it substantially contains organic material. In order to carry out the process, there are certain requisites, which are important to fulfil in order to obtain a high yield of gas, a reasonable processing time, a high plant utilization factor, and low handling costs, namely:

- 1) The process should be continuous, so that the culture of the microorganisms can be maintained for an uninterrupted gas production;
- 2) Biological material should be continuously supplied and removed, so that the capacity of the plant due to volumetric efficiency can be utilized to the greatest possible extent, and any periods of standstill for supply and removal of material will not be required;
- 3) The process should take place at such a temperature that a reasonable processing time and a high gas yield will be obtained;
- 4) The handling of material should be automatic, preferably by means of pumps and not involving any manual labour. These requisites have turned out to be difficult to fulfil by the technique of the prior art, particularly in large plants of capacity in the order of a few or several hundred cubic metres of substrate. Thus, a heating is necessary by use of types of anaerobic microorganisms, which in plants of the said size means a considerable sacrifice of costs with respect to construction and energy.

The present invention seeks to provide a method for the production of methane from cultures of microorganisms from organic waste, by means of which method said requisites may be fulfilled.

The present invention also seeks to provide a plant, which is simple in operation and by means of which the method according to the present invention can be carried out.

According to one aspect of the present invention there is provided a method for producing methane from a substrate containing organic material comprising:

- (i) treating substrate in an ante-chamber at a temperature between 65°C and 75°C , thereby to pasteurise the substrate, and circulating the substrate in the ante-chamber so that it is mixed and maintains an approximately uniform temperature;
- (ii) maintaining a culture of anaerobic microorganisms in contact with substrate in a processing chamber, thereby to generate methane, the temperature of the substrate in the processing chamber being maintained at a temperature between 50°C and 60°C , the substrate being circulated so that it is mixed uniformly and maintains an approximately uniform temperature;
- and performing the following steps continuously or intermittently:
 - (iii) adding additional substrate to the ante-chamber, so that the added substrate is heated by the substrate already in the ante-chamber;
 - (iv) heating the substrate in the ante-chamber so that its temperature is between 65°C and 75°C ;
 - (v) transferring some of the substrate from the ante-chamber to the processing chamber in a manner such that the conditions in the processing chamber are not affected by the transfer to an extent that an overload of the culture of microorganisms occurs;
 - (vi) collecting methane produced in the processing chamber.

According to a second aspect of the present invention there is provided an apparatus when used in a method according to the first aspect of the present invention, comprising:

- a processing chamber adapted to maintain in contact substrate and a culture of anaerobic bacteria, thereby to generate methane;
- an ante-chamber adapted to receive untreated substrate;
- means for heating the ante-chamber to maintain a temperature between 65°C and 75°C ;
- transfer pumping means located in the ante-chamber and adapted to transfer some of the substrate from the ante-chamber to the processing chamber; and
- means for collecting methane produced in the ante-chamber.

Embodiments of an installation according to the present invention will now be described in detail, by way of example with reference to the accompanying drawings, in which:

Fig. 1 shows a central vertical cross-section of a first embodiment of the plant according to the invention;

Fig. 2 shows the same embodiment along the line II—II in Fig. 1;

Fig. 3 shows in detail an alternative arrangement of part of the plant of Fig. 1; and

Figs. 4, 5 and 6 illustrate the second, the third and the fourth embodiment respectively in central cross-sectional views.

Referring first to Fig. 1, a plant according to the first embodiment comprises a cylindrical

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receptacle with an external wall 2, bottom plate 3 and a lid 4 divided into sections, the receptacle being sunken into the surrounding ground 1. The parts 2 and 4 of the receptacle are made in the form of preformed concrete elements, whilst the bottom 3 may be cast on site. An annular wall 5 is concentrically placed inside the external wall 2, the wall 5 being made of concrete and resting on the bottom 3 and supporting the sections of the lid 4 by means of end flanges 6. Thus, the walls 2 and 4 form two spaces, a central chamber 7 inside the wall 5 and an annular chamber 8 between the walls 2 and 5.

An insulating layer 9, 10 and 11, which can be provided with a covering is applied to the outside of the wall 2, the bottom 3 and the lid 4 respectively. The sections of the lid 4 do not meet each other completely, but form a central opening 12, between them which is covered with a lid 13 and an insulated hood 14 above that. The lid 13 is an inspection cover. The lid 4 with the lid 13 tightly close the chambers formed by the chambers 7 and 8. As is shown, the chambers 7 and 8 can be in communication with each other or may be separated by extending the wall 5 up to the lid 13.

An inlet pipe 15 leading from the outside of the receptacle debouches in the chamber 7 inside the wall 5. Inside the chamber 7 there is a transportation system serving to displace the biological substrate. The transportation system comprises a first pumping device 16 and a second pumping device 17, each one comprising an electrically driven pump, e.g. of the centrifugal type. A short inlet feed pipe 18 of the pumping device 16 debouches directly in the chamber 7 adjacent its bottom edge, and an inlet pipe 19 of the pumping device 17 debouches in the chamber 8. Pipes 20 and 21 extend from the respective outlet sides of the pumping device to motor valves 22 and 23 respectively. The motor valve 22 can be changed over so that it either can connect the pipe 20 with an outlet pipe 24 debouching in the chamber 7 or an outlet pipe 25 debouching in the chamber 8. The valve 23 is provided to connect the pipe 21 by means of either a pipe 26 debouching from the plant as described or a tube 27 debouching in the chamber 8.

A tube loop 28 provided in the chamber 7 which is intended to serve as a heating coil, and which is in connection with a heating apparatus via an inlet pipe 29 and an outlet pipe 30. Water may be used as heating medium and is, by way of example, brought to circulate from a boiler through the tube loop 28. There is an additional heating source, formed by a heating cable 31 located between the wall 2 and its insulation 9.

An outlet pipe 32 for gas extends through the lid 4 and debouches in the chamber 8 close to the lid 4 and is in connection with means for the utilization and/or storage of gas.

The transportation means and the heat loop described are also shown as seen from above on an enlarged scale in Fig. 2. An alternative arrangement of the transportation means is shown

in Fig. 3. In this arrangement a pump 48 (seen from above in Fig. 3) is located adjacent the bottom and the periphery of chamber 8. Two pipes 50 and 51 debouch in front of the short outlet feed pipe 49. The pump 48 has an inlet from the underside which is at a certain distance above the bottom of the chamber 8. The pump can be pivoted round a shaft 52 extending in upwards direction through the lid 4. The pipe 50 in the same manner as the pipe 26 extends from the plant and is a substitute for this pipe 26. The pipe 51 extends into the chamber 7. When the pump 48 is in the position shown in Fig. 3, i.e. pivoted away from the pipes 50, 51, it can be used for producing circulation of the substrate in the chamber 8. If the pump 48 is pivoted into a position in front of the pipe 51, mass can be returned to the chamber 7 in order to be heated. When removing substrate from the chamber 8 the pump can be pivoted into a position directly in front of the pipe 50, and the mass is thereby discharged from the plant when the pump is working. The supply of material to the chamber 7 as well as its circulation in the same by the pumping action and transfer to the chamber 8 is provided by means of a pump, which can be changed over by means of a valve, as has been described.

Thus the plant has a first chamber formed by chamber 7, in which heating means and transportation means is provided (the ante-chamber) and a second chamber formed by chamber 8 which contains the biological material during the methane producing process itself (the processing chamber). The embodiments shown in Figs. 4 to 6 are designed according to the same principles but with the difference that both chambers are placed in a larger space intended for storage of the biological material which has been subjected to the gas producing process and which thereafter is intended to be used as fertilizer. Under practical conditions these embodiments may be used in order to serve as a supplementary gas producing plant for new or already existing manure yards of conventional design. What distinguishes the three different embodiments shown in Figs. 4 to 6 respectively is the disposition of the gas producing device mounted in the manure yard in its two chambers.

Thus each one of the embodiments mentioned exhibits a manure yard preferably in the form of an excavation in the ground 33 and substantially comprising a wall 34 and a bottom 35. A wall 37 provided with insulation 36 is installed in a central position in the manure yard, together with an insulated roof 38 and the bottom 35, forming an assembly which encloses the methane producing device. The gas produced is delivered from this device by means of a gas collection pipe 39. In all these embodiments the gas producing device is divided up in an ante-chamber 40 and a processing chamber 41. In the second embodiment as shown in Fig. 4 the division is by means of a horizontal wall 42, in the third embodiment shown in Fig. 5 by means of a

vertical wall 43, and in the fourth embodiment shown in Fig. 6 by means of a circular vertical wall 44.

A heating loop 45 is installed in the respective ante-chamber 40, and an inlet pipe 46 for the biological material also ends in this chamber, which pipe 46 can debouch at the bottom or in an upper portion of the chamber. In order to transfer substrate from the ante-chamber to the processing chamber all of the embodiments are provided with at least one pumping device 47 arranged to transport substrate from the ante-chamber 40 to the processing chamber 41. The transportation means, of which the pumping device is a part has been shown in Figs. 4 and 5 in its most simple arrangement having a single pump with an inlet pipe and an outlet pipe, whereas a more complicated arrangement is shown in Figs. 1 and 6. The design of the transportation means is however not dependent upon the construction of the remaining part of the embodiments, but many combinations are possible.

The roof 38, which is of a hood-like design, in the embodiment according to Fig. 6, can enclose tightly the device inside the wall 37 (with the exception of the gas collection pipe 39) whereas in the embodiment according to Figs. 4 and 5 an outflow of biological material takes place from the processing chamber to the manure yard, the roof therefore being provided as a hood, which is open at its edge but folded down over the wall 37, in which hood the produced gas can be collected.

As mentioned, the material supplied can be of different kinds. The plant shown in Figs. 1 and 2 is intended for processing cowshed manure and intended to serve a fairly large stock of animals. The volume of the chamber 7 can be about 20 cubic metres and the volume of the chamber 8 about 200 cubic metres. The plants according to Figs. 4 to 6 are also intended to be driven by means of cowshed manure, but for use with a smaller number of animals. The device for the production of methane is here limited to the chambers 40 and 41, whereas the space outside of these constitutes a storage space for the substrate which already is processed. For example, space 40 may be 3 cubic metres in volume the space 41 may be 30 cubic metres in volume. Because of the fact that the material in the space 35 does not take part in the process, the size of this space depends primarily upon the frequency of removal of material from it. The manure for the process, which is supplied from a mechanized installation for manure feed, should have a proportion of dry substance of 10 to 15%, so-called liquid manure. Even if the process is continuous, which means that the bacteriological process is never interrupted and an adequate quantity of substrate is always present in the processing stage, this does not mean that the supply and also the removal of material must also be continuous provided only small part quantities of the whole mass are handled at any one time. Thus the feed of the manure can be periodic, e.g. a few times per day, and the manure is then fed into

the process.

Organic material other than manure can also be processed by a method according to the present invention. Parts of plants and vegetable waste and also slaughterhouse waste from by way of example food processing, deep freeze and canning industries can be processed. Also sewer sludge can be processed, provided it does not contain a large proportion of non-biological material, such as sand, clay, industrial waste or similar material. A suitable source may also be the so called water economizing water closet systems, for example, vacuum systems, in which the water supply is very limited, and where the water closet waste is kept apart from the waste water from households, industries and surface water.

If it is assumed that the plant is in operation, the ante-chamber 7 (in Figs. 4 to 6) is substantially filled with freshly introduced biological substrate. This substrate is supplied in a continuous or discontinuous sequence in the way mentioned through the inlet pipe 15 (46) by means of a pumping device not shown. The culture microorganism intended for the methane production has then not yet been fed to the mass. A heating medium, e.g. hot water at a temperature of 60 to 80°C for warming of the biological mass is supplied to the tube loop 28 (45) through the pipe 29. According to the speed of supply the material is fed out of the ante-chamber 7 (40) by means of the pumping device 18 (47) to the processing chamber 8 (41).

Mass is introduced in the ante-chamber 7 by the transportation means shown in Figs. 1 and 2 via the inlet feed pipe 18 and is transported by means of the pump 16 and the pipe 20 to the motor valve 22. If valve 22 is then set to deliver the substrate through the pipe 24, a circulation of the mass in the ante-chamber is obtained by means of the pumping action, and consequently a levelling out of the heat distribution in the mass is obtained. When the mass is to be delivered to the processing chamber 8, the motor valve 22 is changed over, so that the substrate is drawn from the ante-chamber and transported out through the pipe 25 to the processing chamber. Substrate can be drawn from the processing chamber 8 via the inlet pipe 19 by means of the pump 17 and it can subsequently be transported through the motor valve 23 to the processing chamber 8 via the pipe 27. By this arrangement a circulation of the material in the processing chamber by means of the pumping action is possible so that a uniform distribution of the bacteriological culture can be obtained. The circulation by means of the pumping action can alternatively be provided by means of the pump 48 shown in Fig. 3. The substrate is mixed by this circulation and at the same time the cover of foam, which on top of the substrate with the bacteriological culture, and which is impenetrable for the gas, can be broken. When the material is removed from the processing chamber, the motor valve 23 is changed over and the material is passed out through the pipe 26 and further to a collecting station, for example a

manure yard. In the variant according to Fig. 3 the substrate can be pumped out by pivoting the pump 48 right in front of the pipe 50, as already mentioned.

average time that the substrate spends in the process approximately amounts to 10 days.

However, the time the substrate is under treatment in the ante-chamber is not so important, provided that it reaches the desired temperature. It is most advantageous to work the substrate, so that it gets a uniform composition and a levelled out temperature. The best way to achieve this is by mixing. In order to secure a uniform

temperature the supply and removal of the material and its circulation by pumping action can take place according to a determined cycle, viz. first the supply and subsequently the circulation by pumping action for a certain period of time,

before it is taken out, so that the material supplied will have time to acquire the desired temperature.

When the supplied material is manure, the supply usually takes place once or twice during 24 hours. This material is thus mixed by circulation by pumping action in the chamber 7 (40) and thereby gets a uniform temperature and a homogeneous consistency. During the warming up and the mixing certain such as carbon dioxide, may escape depending upon the character of the material. It can be of advantage not to let this gas be mixed with the methane produced. Therefore, the chamber 7 (40) can be closed so that the gas generated in the chamber easily can be removed. The produced methane is taken out from the

separated space 8.

To empty the space 7 (40) into the space 8 (41) suitably small quantities will be pumped out consequently at short intervals, approximately once every hour. By this arrangement the bacteriological process is in the least possible way disturbed by newly supplied material. The pumping out of the material from the space 8 (41) suitably will occur in the same way, approximately once every hour.

According to the present invention the heating of the substrate in the ante-chamber serves to create the desired temperature in the material taking part in the process. However, the heating also has a pasteurizing effect. This effect can be still further increased if the temperature is raised up to or above 65°C, at which temperature pathogenic bacteria of the salmonella family are quickly killed.

However, the material supplied to the processing stage should not have a temperature above 65°C and if it is desired to obtain a pasteurizing effect by increased temperature, it is necessary to reduce the temperature of the mass supplied for the process to approximately 60°C.

This can be achieved by passing the mass through a cooling loop before it is fed to the processing chamber. The emitted heat can be used for preheating material freshly supplied to the ante-chamber. It may therefore be of advantage to split up the ante-chamber into zones: one zone for the intake of the material, where the freshly supplied and unheated material is fed to a cooling loop in which the material to be delivered to the processing chamber 8 (41) is transported; and a second zone, which contains a tube loop with a

The transportation means in the embodiment shown in Fig. 6 is arranged in the same manner. In the embodiments shown in Figs. 4 and 5 however, only one pumping installation is shown, which can transport mass from the ante-chamber 40 to the processing chamber 41. Excess mass, which may have been supplied, is passed out from the processing chamber over the edge of the chamber and flows down in the storage space inside the wall 34. However, these embodiments can also be equipped with more complicated transportation means for the circulation in the different spaces by means of the pumping action.

Heat supply, supply of material and removal of the same are adjusted in such a way that the material, before it is removed from the ante-chamber will have a temperature of 60 to 70°C. The removal of material from the processing chamber is in turn adjusted relative to the supply so that the processing chamber contains a considerable quantity of material, preferably not less than 3/4 of the available volume. The anaerobic microorganisms, which are used for the gas production, are in the substrate in the processing chamber, and during the supply of new substrate, it is infiltrated supplied will successively be subjected to the same and will successively be subjected to the same and will thereby take part in the gas production.

The gas production should take place at the temperature of 55 to 60°C, and thus this temperature has to be maintained in the freshly supplied substrate in the processing chamber. This is achieved by means of good insulation and a certain quantity of heat being supplied by heat transfer from the substrate in the ante-chamber. In order to further compensate for any escape of heat, which can vary according to the season, more or less heat can be supplied by means of heat coil 31 in Fig. 1. In this connection a regulating system of known type can be used with thermal relays, which measure the temperature of the substrate and regulate it.

The material is decomposed by means of the bacteriological culture in the processing chamber 8 and 41 respectively, whereby methane is generated. This gas is taken out in the upper portion of the chamber through the pipe 32 and 39 respectively and is conducted to either one or several kinds of consumption, by way of example heat boilers or gas driven engines and/or to storage spaces for subsequent consumption. The gas can be stored at the pressure at which it is released from the process or be compressed and be stored in pressure vessels.

The material is best utilized for gas production, if this process takes place under mixing of the material. Such a mixing effect is obtained by the stirring action obtained by the circulation of the material by the pumping action described. Supply and removal of material is adjusted so that the

heating medium, to which zone the preheated substrate is passed in order to be heated to the desired maximum temperature before its further transportation through the cooling loop to the processing chamber 8 (41).

Although the mass in the space 7 (40) is heated above 60°C it is not necessary to cool it before it is processed. By transferring the substrate in small quantities to the space 8 (41) as has already been mentioned, an insignificant disturbance of the process will arise, even if the material supplied has a temperature above 60°C. The substrate will also be cooled during the transportation to the space 8 (41).

It has previously been assumed that in bacteriological processes with cultures of anaerobic microorganisms in order to produce methane the temperature should be in the range 30 to 40°C. It has now been proved that production is feasible at temperatures between 50 and 60°C. At such a temperature the process takes a more rapid course, and therefore the installation can be better utilized than at lower temperatures. However a certain sacrifice has to be made, as the quantity of methane per unit of material will be somewhat less than at the lower temperature. An overall estimate comparing quantity of produced gas and capital costs, however, shows that a process carried through at the higher temperature is more advantageous from the point of view of economy. However, at higher temperatures it is important that the temperature is carefully regulated, so that it does not reach the coagulation temperature of protein i.e. about 65°C, which would ruin the bacteriological culture.

The warming up of the material to a pasteurizing temperature, i.e. a minimum of 65°C, is an important phase of the method. The mass of manure produced can be used without falling foul of the restrictions in force in some countries for unpasteurized manure. Thus, the manure can be spread during all seasons and can be used also for horticultural purposes.

The material that has undergone treatment in the process is discharged from the processing chamber and transported to the surrounding manure yard 34, 35 and a separate manure deposit respectively for subsequent use. The material treated in this manner is suitable for use as fertilizer.

The foregoing description has assumed that the plant is in continuous operation. When starting up the process special measures are required however to introduce the culture of microorganisms into the processing chamber. For this purpose special methods and additives are known in order to obtain a secure and quick start of the bacteriological process.

There is a risk that the bacteriological process will cease, and this can occur when the pH-value is incorrect (it should be approximately 6.8), when the temperature is unsuitable (outside of the range of 50 to 60°C), when the mass is exposed to air, when the culture is overloaded (too rapid supply of

fresh material), when too much material is removed in each discharge, or when unsuitable ingredients (e.g. chemicals) are supplied to the biological substrate. When under such

circumstances the process ceases, a new starting up operation is necessary, and this can take place in about the same way as the original one after correction of the cause of the stoppage.

Embodiments of the plant with a compact construction have been described. In all cases the ante-chamber and the processing chamber have been placed in immediate connection to each other. Concentric arrangements or the division of a common receptacle into two chambers by means of a horizontal or a vertical wall have been suggested. However, the invention is not limited to such types of arrangements. The invention can also be used by plants in which the ante-chamber and the processing chamber are located separately from each other and/or on separate levels, in which case they are connected by transportation means for the transfer of the substrate. By such arrangements the plant can be adapted to different types of spaces when the chambers are not located close to each other, the advantage is obtained that the temperature in one chamber will not influence the temperature in the other chamber.

It is not necessary that the ante-chamber is shaped as a proper receptacle but it can for example comprise a pipe loop or a tubular battery, where the substrate is heated for the purpose indicated. The space for the passage through the pipe or the pipes, thus, constitutes the ante-chamber in such a case.

As has been evident from the foregoing description, the receptacle for waste, in which the substrate is collected after having passed the processing chamber, can be separated from the rest of the plant or be integrated in the same way as in the embodiments shown in Figs. 4 to 6. However, the present invention is not limited to any specific arrangement as the receptacle for waste can have any shape and location or it can be divided up in several spaces. It can also be omitted, if the waste is directly transported away to some kind of loading means for removal.

CLAIMS

1. A method for producing methane from a substrate containing organic material comprising:
 - (i) treating substrate in an ante-chamber at a temperature between 65°C and 75°C, thereby to pasteurise the substrate, and circulating the substrate in the ante-chamber so that it is mixed and maintains an approximately uniform temperature;
 - (ii) maintaining a culture of anaerobic microorganisms in contact with substrate in a processing chamber, thereby to generate methane, the temperature of the substrate in the processing chamber being maintained at a temperature between 50°C and 60°C, the substrate being circulated so that it is mixed



heating medium, to which zone the preheated substrate is passed in order to be heated to the desired maximum temperature before its further transportation through the cooling loop to the processing chamber 8 (41).

Although the mass in the space 7 (40) is heated above 60°C it is not necessary to cool it before it is processed. By transferring the substrate in small quantities to the space 8 (41) as has already been mentioned, an insignificant disturbance of the process will arise, even if the material supplied has a temperature above 60°C. The substrate will also be cooled during the transportation to the space 8 (41).

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fresh material), when too much material is removed in each discharge, or when unsuitable ingredients (e.g. chemicals) are supplied to the biological substrate. When under such

circumstances the process ceases, a new starting up operation is necessary, and this can take place in about the same way as the original one after correction of the cause of the stoppage.

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It is not necessary that the ante-chamber is shaped as a proper receptacle but it can for example comprise a pipe loop or a tubular battery, where the substrate is heated for the purpose indicated. The space for the passage through the pipe or the pipes, thus, constitutes the ante-chamber in such a case.

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CLAIMS

1. A method for producing methane from a substrate containing organic material comprising:
 - (i) treating substrate in an ante-chamber at a temperature between 65°C and 75°C, thereby to pasteurise the substrate, and circulating the substrate in the ante-chamber so that it is mixed and maintains an approximately uniform temperature;
 - (ii) maintaining a culture of anaerobic microorganisms in contact with substrate in a processing chamber, thereby to generate methane, the temperature of the substrate in the processing chamber being maintained at a temperature between 50°C and 60°C, the substrate being circulated so that it is mixed

- uniformly and maintains an approximately uniform temperature;
and performing the following steps continuously or intermittently:
- 5 (iii) adding additional substrate to the ante-chamber, so that the added substrate is heated by the substrate already in the ante-chamber;
 - 10 (iv) heating the substrate in the ante-chamber so that its temperature is between 65°C and 75°C;
 - (v) transferring some of the substrate from the ante-chamber to the processing chamber in a manner such that the conditions in the processing chamber are not affected by the transfer to an extent that an overload of the culture of microorganisms occurs;
 - 15 (vi) collecting methane produced in the processing chamber.
 - 20 2. A method according to claim 1, further including the step of transporting treated substrate from the processing chamber at a rate corresponding to the transfer of substrate from the ante-chamber to the processing chamber.
 - 25 3. A method according to claim 1 or claim 2 wherein the amount of dry substance in the substrate entering the ante-chamber is 10 to 15% by weight.
 - 30 4. A method according to any one of the preceding claims, wherein the substrate to be added to the ante-chamber is heated prior to its addition to the ante-chamber by heat exchange with substrate being transferred from the ante-chamber to the processing chamber.
 - 35 5. A method for producing methane from a substrate containing organic material substantially as any one herein described with reference to and as illustrated in the accompanying drawings.
 - 40 6. An apparatus when used in the method according to any one of claims 1 to 5, comprising:
 - a processing chamber adapted to maintain in contact substrate and a culture of anaerobic bacteria, thereby to generate methane;
 - an ante-chamber adapted to receive untreated
 - 45 substrate;
 - means for heating the ante-chamber to maintain a temperature between 65°C and 75°C;
 - transfer pumping means located in the ante-chamber and adapted to transfer some of the
 - 50 substrate from the ante-chamber to the processing chamber; and
 - means for collecting methane produced in the ante-chamber.
 - 55 7. An apparatus according to claim 6 wherein the pumping means is also adapted to circulate the substrate in the ante-chamber.
 - 60 8. An apparatus according to claim 6 or claim 7 wherein in addition to the transfer pumping means, there is provided a second pumping means which is at least partly located in the ante-chamber the second pumping means being adapted to circulate the substrate in the processing chamber and to transfer processes substrate from the processing chamber.
 - 65 9. An apparatus according to claim 7 or claim 8 wherein in addition to the transfer pumping means, a second pumping means is provided in the processing chamber, the second pumping means having a suction orifice and being adapted to pivot between a first position in which the pressure orifice is adjacent an orifice of a conduit extending from the processing chamber, and a second position in which the pressure orifice is directed into the processing chamber, so that the second pumping means either circulates substrate in the processing chamber or transports treated substrate from the processing chamber.
 - 70 10. An apparatus according to any one of claims 6 to 9 wherein the ante-chamber is provided within the processing chamber.
 - 75 11. An apparatus according to any one of claims 6 to 10 wherein the ante-chamber and the processing chamber are provided in a one-piece unit contained within a waste receptacle such that treated substrate is transferred from the processing chamber to the waste receptacle.
 - 80 12. An apparatus according to any one of claims 6 to 11, having a heat exchange zone to which substrate is transferred from the ante-chamber prior to its transfer to the processing chamber and in which zone heat, exchange occurs between the substrate being transferred and the substrate to be added to the ante-chamber.
 - 85 13. An apparatus when used in the method of any one of claims 1 to 4 substantially as herein described with reference to the accompanying drawings.
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