

METHOD OF VENTILATING A ROTARY DRUM

FIELD OF THE INVENTION

5 The present invention concerns the field of rotary drums, in particular the ventilation of rotary drums used for the treatment of fermentable elements where the aim is to reduce the water content, referred to hereinafter for conciseness as "drums". In the field of
10 pre-composting or composting, some drums are referred to as sequential rotary bioreactors or bioreactors-stabilizers. These drums are also used in the agriculture-foodstuffs industry.

15 Conventionally, a drum has a cylindrical overall shape. It is configured to be fed with materials that are at least partly organic, referred to hereinafter as "waste", for example domestic waste or biowaste or sludge mixed with domestic waste. It typically makes it
20 possible to prepare for the separation of the organic fractions from the inorganic fractions of the waste. This preparation is also referred to as "pretreatment" of the waste because it often precedes a process of separation and fermentation (for example composting) or
25 a process of anaerobic digestion of the organic fractions of said waste.

A drum has two ends, a so-called inlet end through which the drum is fed with waste and a so-called outlet
30 end through which the waste is extracted from it after a residency time.

At the inlet of the drum, a unitary volume of waste is introduced at the inlet of the drum via an inlet chute
35 with an inlet flow rate. In some drums an inlet hatch makes it possible to prevent the circulation of moisture from the waste to the equipment situated on the upstream side.

At the outlet of the drum, another volume of waste is extracted at the outlet end of the drum via an outlet hatch with an outlet flow rate, possibly different from the inlet flow rate. The outlet hatch is opened to
5 allow the extraction of a unitary volume of waste from the drum, and then closed after that extraction.

Between these two ends, each unitary volume of waste introduced into the drum is mixed to a greater or
10 lesser degree with the unitary volumes introduced previously and remains in the drum for a so-called residency time, generally several days.

The feeding and the extraction of waste are generally
15 effected so as to have a level of filling of the drum that is more or less constant over time. The drum must not be filled completely with the waste in order to leave an oxygenated gas mixture, in this instance air, in contact with said waste, which enables bacteria, or
20 at least aerobic bacteria, to be able to degrade the organic material.

Outside the introduction and extraction of waste, the ends of the drum are closed by the inlet and outlet
25 hatches.

During the rotation of the drum, because of the action of the aerobic bacteria, the organic material is degraded in the drum. This aerobic degradation
30 generates malodorous volatile molecules (COV, mercaptans, H₂S, etc.) that generally necessitate an appropriate treatment device connected to the drum. This natural process depends on the quality of the aeration, the moisture content and the temperature of
35 the waste. Insufficient ventilation leads to poor degradation of the organic material or a change from aerobic degradation to anaerobic fermentation of the waste.

To prevent the onset of anaerobic fermentation and thus to address this problem, the applicant has already filed application FR1362530 and application FR1362531.

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As satisfactory as the result obtained by these solutions may be, they do not make it possible to regulate the conditions of aerobic degradation and to optimize the separation between the biodegradable fractions and the inert fractions, but merely to
10 maintain aerobic degradation conditions in the drum. It is therefore proposed here to regulate the conditions of aerobic degradation of the waste in a drum in order to improve or accelerate or decelerate that
15 degradation.

SUMMARY OF THE INVENTION

The invention concerns the field of the ventilation of
20 a rotary drum, said drum containing organic material and bacteria, said organic material being for example essentially made up of waste or of elements produced by the agriculture-foodstuffs industry and the moisture content and the composition of which may vary.

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In particular, it makes it possible to regulate the aerobic degradation of said organic material introduced into the drum by regulating the conditions of temperature and/or moisture content and/or oxygen
30 concentration necessary for the growth of the aerobic bacteria.

According to a first of its objects, the invention concerns a method of ventilating a rotary drum, said
35 drum containing organic material and bacteria, the method comprising steps consisting in:

- rotating the drum (100) to cause the waste to move in a direction of movement between an inlet and an outlet of the drum,
injecting gas into the drum (110) by means of at
5 least one ventilation device disposed in the drum,
and
extracting the gas from the drum (120) by means of an extraction device.
- 10 It is essentially characterized in that it further comprises a step consisting in:
regulating (130) the temperature and the flow rate of the injected gas.
- 15 In one embodiment, it further comprises an air recycling step (140) consisting in:
reinjecting into the drum at least some of the gas extracted from said drum.
- 20 In one embodiment, it further comprises a step (150) consisting in:
modifying the temperature of the gas injected or reinjected into the drum by means of a heat-exchange device disposed outside the drum.
- 25 In one embodiment it further comprises a step (160) consisting in:
injecting air into the drum by means of a ventilation device disposed at the outlet of the
30 drum.
- In one embodiment it further comprises a step consisting in:
- 35 heating the injected or reinjected gas at the inlet of the drum (170) by means of a heating device additional to the heat-exchange device.

In one embodiment it further comprises a step consisting in:

5 injecting water into the drum (180) by means of a
 sprinkler device preferably disposed at the inlet
 of the drum.

In one embodiment it further comprises the steps consisting in:

10 analyzing the physical-chemical properties of the
 gas injected or reinjected into the drum (190),
 and
 calculating the rate of degradation of the organic
15 material (200) as a function of said measured
 properties and a reference model.

In one embodiment it further comprises a step (210) consisting in regulating as a function of said analyzed
20 properties and the reference model at least one of the
 following values:

 the flow rate of the flow of gas injected or
 reinjected into the drum,
 the flow rate of the gas extracted from said drum,
25 the temperature of the flow of gas generated in
 the drum,
 the temperature of the flow of gas extracted from
 the drum,
 the temperature of the gas reinjected into said
30 drum.

In one embodiment it further comprises a step (220) consisting in thermally insulating the drum.

35 According to another of its objects, the invention
 concerns a computer program comprising program code
 instructions for executing the method according to the
 invention when said program is executed by a computer.

The method is advantageously independent of meteorological conditions.

5 Thanks to the invention, it is possible to determine when and how much organic material to inject into the drum so that its degradation continues under optimum conditions.

10 The quantity of organic material degraded per unit time is known. It is then possible to control the degradation of the organic material in the drum so that the latter is above a threshold value or the rate of rejection is below a threshold value. By rate of rejection is meant the ratio between the mass of
15 material that cannot be valorized and that is inert at the outlet of the drum and the total mass of material treated in the drum. It is expressed as a percentage and generally defined contractually.

20 The quantity and the quality of the material degraded per unit time is in fact a function of the characteristics of the organic material introduced into the drum and the microbial activity in the drum.

25 The person skilled in the art knows that optimum mesophilic aerobic microbial activity is obtained at a temperature between 20 and 45° inclusive and a moisture content of 45 to 65% and that optimum thermophilic microbial activity is obtained at a temperature between
30 50 and 70° inclusive and a moisture content of 30 to 65%. The oxygen concentration must also be sufficient.

The person skilled in the art also knows that the microbial activity in a drum can be measured by at
35 least one of the following physical-chemical characteristics: the increase in temperature of the organic material in the drum and therefore indirectly that of the gas present in the drum, the increase in

the CO₂ concentration in the drum, the increase in the relative humidity of the organic material and indirectly of the gas present in the drum.

5 The present invention is therefore aimed at measuring and then regulating at least one of the foregoing characteristics by acting on the ventilation and/or the sprinkling in the drum as a function of the characteristics of the waste introduced into the drum.

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Other features and advantages of the present invention will become more clearly apparent on reading the following description given by way of illustrative and nonlimiting example and with reference to the appended
15 figures.

DESCRIPTION OF THE DRAWINGS

- figure 1 illustrates one embodiment of the method
20 according to the invention,

- each of figures 2 to 6 illustrates one particular embodiment of a device able to implement one embodiment of the method according to the invention. In figures 2
25 to 6 fresh air is symbolized by a chain-dotted line and extracted air is symbolized by a solid line.

DETAILED DESCRIPTION

30 For conciseness:

- the terms "composting drum", "pre-composting drum", "rotary drum" and "drum" are used interchangeably;
- 35 - "inlet" and "outlet" refer to the inlet and to the outlet of the drum;
- the terms "organic material" and "waste" are used interchangeably", whether industrial or domestic;

- by "a" drum or "the" drum is also meant two drums mounted in series where the waste from the outlet of one is at least partially introduced into the inlet of the other or in parallel if the capacity of the installation requires it;
- by "the" sensor or "a" sensor is meant a set of at least one sensor;
- by "air" extracted or reinjected is meant all gases extracted from the drum or reinjected into it.

Structure

In the conventional way, a drum 10 comprises an inlet end IN, an outlet end OUT, an essentially cylindrical main body, an inlet hatch, here mounted on a feed chute, and an outlet hatch. Waste is introduced into the drum via the inlet hatch.

The drum preferably comprises a hood 11, mounted in the upper part of said drum, that is to say in the part above a horizontal plane passing through the rotation axis of the drum, and disposed toward the outlet end, that is to say between the middle of the drum and the outlet end of the drum. The interior shape of the hood preferably espouses the exterior shape of the drum. Here the hood has an annular internal shape.

The drum further comprises at least one louver. A louver is an opening, or through-hole, in the main body. A louver is constrained to rotate with the drum. A plurality of louvers is preferably provided, disposed according to a radial symmetry of the drum.

There is also provided at least one ventilation device enabling ventilation (or interchangeably aspiration, injection, insufflation or blowing) of air into the drum.

The ventilation device comprises for example at least one of the following elements: fan, compressor, injector, nozzle, air pump, etc., that is to say any
5 device configured to inject into the drum an oxygenated gaseous substance, in this instance air.

The injection of air by the given ventilation device is controlled by a control device comprising a computer.
10

The computer stores a reference model making it possible to calculate the energy and materials balance thanks to an energy equation and to the various sensors and measuring instruments installed on the drum or the
15 ventilation ducts. The energy and materials balance makes it possible to calculate the energy flow, the flows of carbon and water produced by the bacteria at any time, that is to say the rate of degradation of the organic material, independently of the external
20 conditions. It is therefore possible to average the results of the balance over predetermined time periods, for example hour by hour or day by day.

Air is injected or aspirated when said ventilation
25 device is not in contact with the waste, that is to say when it is in the upper part of the drum. The flow rate of the air injected or aspirated is adjustable.

The internal pressure in the drum is preferably lower
30 than atmospheric pressure so as to limit the risks of emanation of odors in the event of a leak from the drum.

At least one controlled extraction device may be
35 provided, typically an extractor or a pump, making it possible to extract air from the drum and typically mounted in the hood 11. The extracted gas is sent to an odor treatment device 40 or recycled.

The ventilation device is preferably connected to the inlet end of the drum and the extraction device to the louvers via the hood.

5

The gas extracted by the extraction device may advantageously be at least partly reintroduced or reinjected at the inlet of the drum.

10 The louvers are preferably disposed between the outlet end of the drum and the first third of the total length of said drum starting from the outlet end.

A device is advantageously provided for selectively
15 blocking the louvers, making it possible to uncover a given louver in the open position and to cover the louver in the closed position, two embodiments of which device are described hereinafter.

20 A selective blocking device is preferably provided for each louver.

At least some louvers are disposed according to a radial symmetry and facing the hood so that the
25 rotation of the drum brings at least one louver under the hood on each revolution.

A selective blocking device makes it possible to uncover (open) or cover (close) each louver
30 selectively, in this instance thanks to a mobile blocking member.

An extraction device, or extractor, comprises at least one extraction orifice intended to be as close as
35 possible to the external face of the drum, that is to say the louvers. A plurality of extraction orifices may be provided, making it possible to extract air via a plurality of orifices, possibly simultaneously. The

extractor is connected to the hood, for example, said hood comprising at least one extraction orifice.

5 The drum may be equipped with a device for controlled sprinkling of the waste.

10 A heat-exchange device 30 is also provided, in this instance a heat-exchanger, disposed outside the drum, making it possible to modify the temperature of the gas injected or reinjected into the drum. The heat-exchanger notably makes it possible to dry the extracted gas before it is transported to an odor treatment device or, where applicable, before it is reinjected into the drum. Drying the extracted gas also
15 makes it possible to modify the relative humidity of the extracted gas and therefore to optimize the transport and extraction of wet gas from the drum.

20 The drum may be thermally insulated by covering its periphery with thermal insulation, preferably over the entire length of the drum. The thermal insulation makes it possible to limit the loss of heat from the drum to the atmosphere regardless of the season or to limit the ingress of heat.

25

Ducts

The ducts are preferably thermally insulated.

30 A network of ducts is provided making it possible at least to feed the gas at the inlet of the drum and to extract the gas from the drum by means of the extraction device.

35 The duct network comprises at least:

- an extraction duct, and

- an inlet duct, and the network preferably further comprises
- a fresh air duct.

5 The fresh air duct makes it possible to transport gas, in this instance air, from a source 20 of fresh air to a fresh air outlet. A source of fresh air may be the atmosphere, a compressed air network, or both. A fresh air outlet may be the atmosphere, the inlet duct, or
10 both. The fresh air duct may be connected to the heat-exchanger.

The heat-exchanger is preferably equipped with a bypass and a controllable valve making it possible to control
15 the proportion X of fresh air entering the heat-exchanger and the proportion $100\% - X$ of fresh air in the bypass, where X is a proportion between 0 and 100% inclusive.

20 The extraction duct makes it possible to extract the gas from the drum, that is to say to transport the extracted gas from the drum to an extracted gas outlet.

The extraction duct is connected to the extraction
25 device.

An extracted gas outlet may be an odor treatment device, the inlet duct, or both. The extracted gas duct may be connected to the heat-exchanger.

30

The heat-exchanger is preferably equipped with a bypass and a controllable valve making it possible to control the proportion Y of extracted gas entering the heat-exchanger and the proportion $100\% - Y$ of extracted gas
35 in the bypass, where Y is a proportion between 0 and 100% inclusive.

The inlet duct is connected to the ventilation device.

The inlet duct makes it possible to inject or to reinject inlet gas into the drum, in this instance fresh air, extracted gas or a mixture of both.

5

The inlet duct may be connected to the fresh air duct, to the extraction duct, or both.

The inlet duct may be connected to the heat-exchanger.

10

The inlet duct is preferably equipped with a controllable valve making it possible to control the proportion Z of fresh air and the proportion $100\% - Z$ of extracted gas in said inlet duct if the two are mixed.

15

In a variant, instead of or combined with the embodiments described above, a heat source is provided outside the drum and able to heat a fluid, for example an incinerator, a solar panel or a methanizer. The fluid is able to circulate in an additional duct connected either to said heat-exchanger or to an additional heat-exchanger.

20

25 Sensors

The drum may be equipped with a temperature sensor, making it possible to execute a step consisting in measuring, preferably continuously, the temperature of the waste in the drum or the temperature of the gas in the drum.

30

A sensor may be provided for measuring the flow rate of gas, preferably positioned in the vicinity of the extraction device, in the drum or in the extraction duct.

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A sensor may be provided for measuring the oxygen concentration of the injected or reinjected gas, for example an oxygen probe. The sensor for measuring the oxygen concentration is preferably disposed in the vicinity of the inlet of the drum and for example in the inlet duct or in the drum.

A sensor may be provided for measuring the moisture content in the drum.

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A sensor may also be provided for measuring the quantity of at least one of the following gases: CO₂, CO, CH₄ and H₂S, preferably disposed in the drum or at its outlet, for example in the extraction duct.

15

Operation

The drum is rotated to cause the waste to move in a direction of movement between the inlet and the outlet of the drum.

20

Air - new, extracted or a mixture of the two - is injected into the drum, preferably at a controlled flow rate, by means of at least one ventilation device disposed in the drum. Air notably makes it possible to feed the aerobic bacteria with oxygen.

25

Air is extracted from the drum, preferably at a controlled flow rate, by an extraction device. The extraction device notably makes it possible to evacuate heat and steam produced by the bacteria.

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During the residency time of the waste, some bacteria produce heat. Now, bacterial activity notably depends on heat.

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Here an astute use of the heat produced by the bacteria in the drum is proposed, notably using the heat produced by them to regulate their activity.

5 Temperature regulation

There is provision for adjusting the temperature and the flow rate of the air (fresh or extracted) injected into the drum, in this instance by means of a computer.

10

The computer controls the extracted gas flow rate and the injected or reinjected gas flow rate by means of a computer program loaded into memory and comprising a regulation algorithm, in particular of PID type. The regulation effected by the algorithm depends for example on at least one of the following parameters: the nature of the waste in the drum, the dimensions of the drum, the volume of waste in the drum, its biomass concentration, its relative humidity, the diameter of the ducts.

20

The computer preferably also holds in memory at least one of the proportions X, Y and Z. It can therefore also control the valves that make it possible to regulate the proportion of fresh air, extracted gas and inlet gas entering the heat-exchanger, the bypass and the inlet duct.

25

The temperature of the gas in the drum can be modified by the temperature of the air (fresh or extracted) injected or reinjected. Moreover, the temperature of the gas in the drum may be modified by the flow rate of the air injected into the drum or the recirculation of the extracted gas.

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The temperature of the air (fresh or extracted) injected or reinjected may be modified by means of the heat-exchanger.

It is therefore possible to control the valve of the heat-exchanger as a function of the value X in memory, which may be variable, so that the temperature of the gas injected or of the gas extracted and reinjected into the drum is equal to a predetermined value stored in a memory.

Regulation of Oxygen Concentration

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The oxygen concentration of the gas contained in the drum may be modified by controlling the extraction of extracted gas or the injection of fresh air, fresh air having a higher oxygen concentration than the extracted gas.

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The oxygen concentration of the fresh air is known. By measuring the oxygen concentration of the extracted gas, for example by means of an oxygen probe, it is possible to control the valve of the inlet duct as a function of the value Z in memory, which may be variable, so that the oxygen concentration of the air reinjected into the drum is equal to a predetermined value stored in a memory.

25

Regulation of Relative Humidity

There may be provision for injecting water into the waste before its introduction into the drum or in the drum by means of a sprinkler device, for example injection nozzles.

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The relative humidity of the gas in the drum depends on its temperature. Within a certain limit, the hotter the gas, the greater its capacity to transport moisture.

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It is therefore possible to regulate the extracted water flow rate by regulating the flow rate of gas extracted from the drum in addition to its temperature.

- 5 Moreover, when the extracted gas enters the heat-exchanger, because the extracted gas is hotter than the fresh air, the extracted gas is condensed.

10 It is therefore possible to control the valve of the heat-exchanger as a function of the value Y in memory, which may be variable, so that the moisture content of the extracted gas and reinjected into the drum is equal to a predetermined value stored in a memory.

15 Examples

The following examples are purely illustrative. The proposed method may function according to one of the examples described for a certain period and then
20 according to another of the examples described for a certain time period.

1. In one embodiment, figure 2, the extracted gas is sent directly to an odor treatment device 40. Fresh air
25 is injected directly into the drum. By "directly" is meant without passing through the heat-exchanger.

The temperature of the gas in the drum is essentially conditioned by that of the fresh air and by the
30 bacterial activity.

This mode of operation makes it possible to introduce into the drum the necessary quantity of oxygen as a function of the waste to be treated and to dry the
35 required quantity of moisture in the degraded waste.

2. In one embodiment, figure 3, the extracted gas is sent to an odor treatment device 40 via the heat-

exchanger 30 and fresh air is injected into the drum via the heat-exchanger 30.

5 This embodiment makes it possible to preheat the fresh air uniquely by means of the temperature of the gas extracted from the drum.

10 3. In one embodiment, figure 4, the extracted gas is reinjected directly into the drum.

This embodiment makes it possible to increase the temperature of the gas in the drum.

15 4. In one embodiment, figure 5, the extracted gas is reinjected into the drum via the heat-exchanger and the fresh air passing through the heat-exchanger is evacuated, that is to say is not injected into the drum; for example it is discharged to the atmosphere or used for other purposes.

20 This embodiment makes it possible to reduce the temperature of the extracted gas that is reinjected and, through the phenomenon of condensation, to reduce its relative humidity.

25 5. In one embodiment, figure 6, the extracted gas is sent to an odor treatment device 40 via the heat-exchanger 30; a proportion X of fresh air entering the heat-exchanger 30 is injected into the drum and the
30 proportion $100\% - X$ of fresh air in the bypass is injected into the drum.

35 This embodiment makes it possible to pre-heat the fresh air slightly before its injection into the drum and to regulate the relative humidity of the gas in the drum by condensing the extracted gas.

The embodiments illustrated in figures 2 to 6 are purely illustrative. Other embodiments can be envisaged combining some or all of at least two of the embodiments shown.

5

There is also provision for analyzing and measuring at least one of the following physical-chemical characteristics: the pressure, flow rate, temperature and composition (CO₂, H₂O, oxygen, etc.) of the gas
10 injected or reinjected or extracted in the drum.

Using these analyses and the reference model, it is then possible to calculate the rate of degradation of the organic material.

15

It is therefore possible to optimize the degradation of the organic material, and the physical-chemical conditions of the organic material at the outlet from the drum are controlled, which makes it possible to
20 optimize the refining of the waste downstream of the drum.

For example, at least one of the following values may be regulated as a function of said analyzed properties
25 and the reference model:

- the flow rate of the flow of gas injected or reinjected into the drum,
- the flow rate of the gas extracted from said drum,
- 30 - the temperature of the flow of gas generated in the drum,
- the temperature of the flow of gas extracted from the drum, and
- the temperature of the gas reinjected into said
35 drum.

For example, if the internal temperature measured in the drum is too low, that is to say is below a

threshold value stored in a memory, it is considered that the conditions for optimal degradation are not satisfied and that more heat must be applied. In this case, the aeration of the drum operates in a closed
5 circuit to increase the heat.

If the internal temperature measured in the drum is too high, that is to say is above a threshold value stored in a memory, then the flow rate of fresh and dry air
10 introduced into the drum is increased and the gas is evacuated from the drum to the odor treatments.

There may be provision for measuring the temperature and the moisture content of the atmospheric air, for
15 example by means of a weather station, in particular if the reference model includes such measurements by way of parameters.

The invention is not limited to the embodiments
20 described above.

For example there may be provision for heating the air injected at the inlet of the drum by means of a heating device additional to the heat-exchange device, outside
25 the drum or disposed inside it and preferably controlled by the computer.

There may be provision for injecting air into the drum by means of a ventilation device disposed at the outlet
30 of the drum. In this case, the extraction device is advantageously between the center of the drum and the outlet end and preferably situated at one third of the total length from the outlet end.

35 The use of injection or reinjection via the inlet generates a flow in the direction of movement of the waste and the operation of the ventilation device

disposed at the outlet generates a flow in the opposite direction to the flow of the waste.

Between the inlet and the extraction device, the waste
5 is degraded as explained above and between the
extraction device and the outlet the waste is dried by
means of the contraflow of air.

CLAIMS

1. A method of ventilating a drum (10), said drum containing organic material and bacteria, the method comprising steps consisting in:
 - rotating the drum (100) to cause the waste to move in a direction of movement between an inlet (IN) and an outlet (OUT) of the drum,
 - injecting gas into the drum (110) by means of at least one ventilation device disposed in the drum, and
 - extracting the gas from the drum (120) by means of an extraction device,characterized in that it further comprises the steps consisting in:
 - regulating (130) the temperature and the flow rate of the injected gas, and
 - interrupting the injection of gas into the drum (110) by obstructing said ventilation device by means of a selective obstruction device.
2. The method according to the claim 1, further comprising an air recycling step (140) consisting in:
 - reinjecting into the drum at least some of the gas extracted from said drum.
3. The method according to any one of the preceding claims, further comprising a step (150) consisting in:
 - modifying the temperature of the gas injected or reinjected into the drum by means of a heat-exchange device disposed outside the drum.
4. The method according to any one of the preceding claims, further comprising a step (160) consisting in:
 - injecting air into the drum by means of a ventilation device disposed at the outlet of the drum.

5. The method according to any one of the preceding claims, further comprising a step consisting in:

- heating the injected or reinjected gas at the inlet of the drum (170) by means of a heating device additional to the heat-exchange device.

6. The method according to any one of the preceding claims, further comprising a step consisting in:

- injecting water into the drum (180) by means of a sprinkler device preferably disposed at the inlet of the drum.

7. The method according to any one of the preceding claims, further comprising the steps consisting in:

- analyzing the physical-chemical properties of the gas injected or reinjected into the drum (190), and
- calculating the rate of degradation of the organic material (200) as a function of said measured properties and a reference model.

8. The method according to claim 7, further comprising a step (210) consisting in regulating as a function of said analyzed properties and the reference model at least one of the following values:

- the flow rate of the flow of gas injected or reinjected into the drum,
- the flow rate of the gas extracted from said drum,
- the temperature of the flow of gas generated in the drum,
- the temperature of the flow of gas extracted from the drum,
- the temperature of the gas reinjected into said drum.

9. The method according to any one of the preceding claims, further comprising a step (220) consisting in thermally insulating the drum.

10. A computer program comprising program code
instructions for executing the method as claimed
in any one of claims 1 to 8 when said program is
5 executed by a computer.