

SPECIFICATION

Growth of biological material

- 5 This invention concerns a process wherein biological material is grown from a supply of suitable nutrient material, and apparatus for carrying out said process.

Examples of processes with which the invention is concerned and which are practised industrially are biological fermentation processes of various kinds and the treatment of sewage or industrial effluent by the so-called activated sludge process.

- The present invention is based upon an appreciation of the possibility of providing biomass within a reaction vessel such that the volume of biomass present is accurately known and is present in packages of known size and form. In this way the concentration of biomass can be sustained at an optimum level and the age of the biomass and therefore the overall yield from reactions, as well as the nature of those reactions themselves, can be determined and controlled.

- According to the present invention, there is provided a process wherein a biological material is grown from a supply of suitable nutrient material, comprising the steps of providing a vessel in which is contained a biological material support medium in the form of at least one body defining within its internal structure a substantial voidage such as to provide an environment which will support and contain biological material as a substantially integral mass within said voidage, there being an extensive area of access from the outer surface of the or each said body to the voidage therein; causing the nutrient and any additional substances required for the process to contact and enter the support medium within the vessel there being relative movement between the support medium and the walls of the vessel during the growth process; and restricting accumulation of biological material outwardly from the outer surface of the or each said body.

The restriction of such outward growth can be achieved by continual or periodic removal of such material or by removal of the body or bodies from the vessel before such outward growth occurs.

- Preferably the voidage within the internal structure of each said body is such that the biological material supported by and contained within said body tends to be present as an integral mass.

The invention also includes apparatus for carrying out the process as aforesaid.

In one preferred form of apparatus there is provided a reaction vessel which contains a multiplicity of said bodies, each of which:-

- (a) is of such shape as to enable the bodies to move relative to one another with a rubbing and-or knocking action without packing together as a solid unit;
- (b) has an outer surface of such character that the bodies do not interlock with one another during such relative movement;
- (c) has substantial voidage within its internal structure; and
- (d) has an extensive area of access from its outer

surface to such voidage;

means for passing fluid containing the nutrient material and other substances necessary to support the reaction through the vessel under such

- condition that there is some movement of the individual bodies relative to one another such that biological material which grows outwardly from the outer surfaces thereof is released through attrition.

In an alternative preferred form of apparatus for carrying out the method aforesaid there is provided a reaction vessel containing a multiplicity of said bodies each of which:-

- (a) has an outer surface of such character that the bodies do not interlock with one another during relative movement;
- (b) has substantial voidage within its internal structure; and
- (c) has an extensive area of access from its outer surface to such voidage;

means for introducing said bodies free or substantially free of biological matter to the vessel and means for removing bodies supporting and substantially filled with biological matter from the vessel, the residence time of bodies in the vessel being such that they are removed before growth of biological matter outwardly from their outer surfaces occurs.

The invention will be further apparent from the following description with reference to the several figures of the accompanying drawings which show, by way of example only, two forms of apparatus for the treatment of sewage effluent by the so-called activated sludge treatment process and embodying the invention.

- Of the drawings:-

Figure 1 shows a partially cut-away side elevation of the first form of apparatus;

Figure 2 shows a partially cut-away side elevation of the second form of apparatus;

- Figure 3 shows a perspective view of one of the bodies of the apparatus of Figure 1 or Figure 2 and on an enlarged scale; and

Figure 4 shows a perspective view of an alternative form of body for the apparatus of Figure 1 or Figure 2, again on an enlarged scale.

- In the conventional activated sludge treatment process, sewage or industrial effluent is aerated and agitated within a vessel in the presence of a biological population which metabolises on various impurities contained within the effluent and grows to produce so-called secondary sludge which can be removed from the effluent by sedimentation. The concentration of biological population within the treatment vessel will vary with changes in composition of effluent, residence time and numerous other factors but will in any event be limited with the result that the treatment vessel will need to be much larger than would be necessary if higher concentrations of biological population could be sustained.

Referring now to Figures 1 and 3 of the drawings, it will be seen that the first form of apparatus is essentially comprised by a vertically extending cylindrical column forming a reaction vessel generally indicated at 10. The vessel 10 is closed

adjacent its lower and upper ends by perforate plates 11 and 12 respectively. The space between the plates 11 and 12 is partially filled with a multiplicity of bodies 14 whose structure will be described in greater detail hereinafter. Each of the bodies 14 however supports and contains biomass forming part of the total biological population contained within the vessel 10.

Effluent, in this case sewage effluent derived from raw sewage after screening and, if required, primary sedimentation thereof, is passed upwardly through the vessel 10 by introduction through the line 15 to a chamber 16 located beneath the plate 11. Liquid leaves the upper end of the vessel 10 by passage through the apertures in the plate 12 to overflow into a collecting main or gutter 17 which is connected by a line 18 to the chamber 16 by way of a pump 19 which serves to recycle a portion of the liquid, excess liquid (equal to the inflow through line 15) being led away through the line 20 on the pressure side of the pump 19.

Air is supplied separately to the chamber 16 from a compressor 22 via a line 23.

As the effluent and air flow upwardly through the vessel 10 they react with the biological population supported and contained within the bodies 14 causing breakdown of various substances including carbonaceous and proteinaceous materials to produce carbon dioxide and additional biomass which grows outwardly from the bodies 14.

The bodies 14 do not pack the space between the plates 11 and 12 tightly, whereby the flow of gas and liquid through the vessel 10 causes some movement of the bodies 14 relative to one another within the bed. This movement is such as to cause the outer surfaces of the bodies 14 to rub and/or knock against one another, thus causing them to shed through attrition excess biomass as it builds up on their outer surfaces. Contact of the bodies with the walls of the vessel 10 and the flow of liquid over the bodies can also contribute to the release of excess biomass.

We have found that the concentration of biomass per unit volume of the reaction vessel utilising bodies of the kind with which we are here concerned can be greater by a factor of up to 5 than the concentration of biomass in a conventional aeration tank with the result that the capacity of the treatment vessel for a given throughflow of effluent can be approximately 1/5 of that of the conventional vessel with a consequent and substantial reduction in the capital cost of a treatment plant, assuming equal biomass activity in both situations.

The bodies 14 are of special construction. Their overall shape is preferably generally rounded or sufficiently so to enable them to move relative to each other with a rubbing and/or knocking action without packing together as a solid unit. Again, the outer surfaces of the bodies are of such character that they do not interlock with one another during such relative movement. The bodies have substantial voidage within their internal structure, that is to say their bulk density in air is substantially less than the density of the material from which they are formed. Each body has an extensive area of access from its outer surface, as by way of a

multiplicity of openings or cavities, to such voidage. The voidage is preferably such that the volume of biomass which is supported and contained by each body is generally present as an integral mass or monolithic structure.

The bodies can be made from metal such as stainless steel, certain synthetic plastics, glass or other non-corrodible materials. The bodies may be of sponge-like construction or of reticular construction or of other form.

Various modifications are possible. For example, the reaction vessel may contain bodies of different size which will classify within the bed. Such different sized bodies might support different kinds of organism whereby different kinds of reaction may take place in the reaction vessel simultaneously.

Referring now to Figures 2 and 3 of the drawings, it will be seen that the second form of apparatus is essentially comprised by a vertically extending cylindrical column forming a reaction vessel generally indicated at 50. The upper end of the vessel 50 is closed by a perforate plate 51 and surrounded by a collecting main or gutter 52 whose function will be apparent hereinafter.

The vessel 50 contains a multiplicity of bodies 14, each of which is adapted to support and contain biomass forming part of the biological population contained within the vessel 50. The bodies 14 are similar to those described in connection with the apparatus of Figure 1, and formed from a material which is less dense than water.

A duct 53 communicates with the interior of the vessel 50 adjacent its upper end, and serves to supply the bodies 14, free of biomass or substantially so, into the vessel 50.

Sewage effluent derived from raw sewage after screening and, if required, primary sedimentation is introduced into the base of the vessel 50 through a line 54 together with air which is supplied from a compressor 55 into the vessel by way of diffusers 56.

As the effluent liquor and air pass upwardly through the vessel 50 various impurities, such as carbonaceous and proteinaceous material, contained within the effluent liquor, are metabolised by the biological population contained within the vessel 50.

The effluent liquor leaves the top of the vessel 50 through the perforations in the plate 51 to be collected in the main or gutter 52. The majority of the liquor flowing into the main or gutter 52 is recycled by means of a pump 57 to a line 58 for reintroduction to the vessel 50 at the base thereof. A smaller portion, equal to the feed through the line 54 is led off for further treatment through line 59.

Bodies 14 are removed from the vessel adjacent the base thereof through line 60 together with some of the effluent liquor. The mixture of bodies 14 and effluent liquor is passed to a straining device 61 which passes the liquor through the line 62 to the suction side of the pump 57 and the separated bodies through line 63 to a machine 64 which separates biomass supported by and contained within the bodies from the bodies themselves. The separated biomass is removed through line 65 as secondary sludge, whilst the bodies 14 freed of

biomass are passed through line 66 for supply to the duct 53.

It will be understood that the bodies are continuously recycled through the vessel 50. As the bodies 14 move downwardly through the vessel they gradually support and contain progressively more biomass, either becoming seeded with biomass contained within the recycling effluent liquor or being seeded by virtue of incomplete removal of biomass in the machine 64.

The apparatus is designed so that the residence time of the bodies within the vessel 50 is such that they are removed when they are substantially filled with biomass but before biomass grows outwardly from their outer surfaces.

The machine 64 may separate biomass from the bodies 14 by intense vibration or other mechanical method. As an alternative, the bodies 14 may be freed of biomass for re-use by a chemical or biological method such as extended aeration, for example.

The flow of liquor and air through the vessel 50 is such as to fluidise the bed of bodies 14 sufficiently to enable the bodies 14 to classify within the bed so that the apparatus operates in the manner described.

As with the first form of apparatus described, the concentration of biomass per unit volume of reaction vessel can be significantly greater than possible with the conventional activated sludge process.

Furthermore, the surplus recovered biomass will contain a smaller proportion of free (that is to say extra-cellular) water than conventional secondary sludges rendering dewatering to a combustible state more easy.

Various modifications are possible.

Thus, for example, if the bodies are made from a non-combustible material the excess biomass contained therein may be removed by combustion. Equally if the bodies are formed from a combustible material they may be burned with the included biomass, fresh bodies being supplied continually instead of recycling a given quantity thereof.

Again, for example, the bodies may be formed from a material more dense than water and passed through the vessel in the opposite direction, that is from bottom to top under the effect of the upward flow or effluent and air in the vessel.

It will be understood that in both forms of apparatus described the quantity of biomass present in the reaction vessel at any time is reasonably accurately known as is the size and shape of the units or packages in which it is present and that control of the reaction can thus be more precise and predictable than has been possible hitherto with conventional apparatus.

Various interesting possibilities exist. For example, in either of the forms of apparatus described the bodies may be of such size that a sufficiently large volume of biomass is supported and contained whereby essentially aerobic processes take place at the surface of each body and within an internal layer adjacent such surface whilst essentially anaerobic processes such as the conversion of nitrates to nitrogen gas occur in the

interior of the body in the deeper layers of biomass.

It must be understood that the size of body necessary to ensure that both aerobic and anaerobic processes take place will be dependent upon the dissolved oxygen level within the reaction vessel. It follows that the size of the body can be selected for a given dissolved oxygen level or the dissolved oxygen level can be adjusted for a given body size to give the desired level of both aerobic and anaerobic processes. Normally the desired level will be that which minimises biomass production.

One suitable body for use in the apparatus described with reference to either Figure 1 or Figure 2 is as illustrated in Figure 3 and may be made from a single length of plastic monofilament which is knitted to form a piece of fabric in the form of a cylindrical tube which is then rolled into toroidal shape. In a typical example the toroid will have a diameter of 5 cm. or thereabouts and a thickness of 2 cm or thereabouts.

This body is easily mass-produced and inexpensive and therefore attractive in applications where large quantities are required as, for example, in the treatment of sewage or industrial effluent.

Another suitable body is as shown in Figure 4 and may be made from a single length of stainless steel wire which is knitted, again to form a cylindrical tube, a length of which is compressed into a generally spherical form. This body is relatively expensive but is more suitable for applications where bodies of smaller size having a diameter of 0.6 cm, for example, are required. Bodies made from stainless steel may be of particular interest where fine chemicals such as pharmaceuticals are to be produced.

It will be appreciated that it is not intended to limit the invention to the above examples only, many variations, such as might readily occur to one skilled in the art, being possible without departing from the scope thereof.

For example, instead of providing the bodies within a static vessel through which the materials to be treated are passed, the bodies may be contained within an open cage-like vessel which is itself moved through the materials to be treated. Such a cage-like vessel might take the form of a rotatable drum which is at least partially immersed in a body of liquid containing materials to be reacted.

Yet again, for example, the bodies may be contained within an open tank-like vessel which is continually stirred with sufficient vigour to cause the bodies to shed excess biomass through liquid shear or by attrition resulting through collision.

Whilst the necessary nutrients will normally be passed over the support structure for the biological material in the form of a liquid together with such gaseous additives as may be necessary to support the required reactions, there may be applications where the necessary nutrients can be present in gaseous, mist or vapour form together with sufficient moisture to sustain the biological reaction.

Whilst we have described the invention with reference to the treatment of effluents, it will be understood that the techniques are applicable to any process wherein biological material is grown from a

source of nutrient. Thus the techniques may be applied to the production of pharmaceutical substances and single cell proteins such as yeast. It is envisaged, for example, that fermenters used in the brewing and related industries might usefully contain the necessary yeast within bodies of the general kind which we have described.

It will be understood that the bodies, even whilst empty, may serve to act as a filter in the apparatus described with reference to Figure 2 and in some applications such filtration effect might be advantageous.

CLAIMS

1. A process wherein a biological material is grown from a supply of suitable nutrient material, comprising the steps of providing a vessel in which is contained a biological material support medium in the form of at least one body defining within its internal structure a substantial voidage such as to provide an environment which will support and contain biological material as a substantially integral mass within said voidage, there being an extensive area of access from the outer surface of the or each said body to the voidage therein; causing the nutrient and any additional substances required for the process to contact and enter the support medium within the vessel there being relative movement between the support medium and the walls of the vessel during the growth process; and restricting accumulation of biological material outwardly from the outer surface of the or each said body.

2. A method according to Claim 1, wherein the restriction of accumulation of biological material outwardly from the outer surface of the or each said body is effected by continual or periodic removal of material growing outwardly from said outer surface.

3. A method according to Claim 1, wherein the restriction of accumulation of biological material outwardly from the outer surface of the or each said body is effected by removal of the body or bodies from the vessel before such outward growth occurs.

4. A method according to Claim 2, wherein said vessel contains a multiplicity of said bodies, and fluid containing the nutrient material is passed through the vessel under such conditions that there is movement of the individual bodies relative to one another such that biological material which grows outwardly from the outer surfaces thereof is released through attrition.

5. A method according to Claim 3, wherein said vessel contains a multiplicity of said bodies and fluid containing the nutrient material is passed through the vessel under such conditions that there is some movement of the individual bodies relative to one another, bodies being continually or periodically removed from the vessel when supporting and substantially filled with biological material, the residence time of the bodies in the vessel being such that they are removed before growth of biological material outwardly from their outer surfaces occurs, bodies which are free or substantially free of biological material being introduced into the vessel to replace those removed.

6. Apparatus for carrying out a process wherein a biological material is grown from a supply of suitable nutrient material, comprising a reaction vessel, a biological material support medium contained within the vessel; said support medium comprising at least one body defining within its internal structure a substantial voidage such as to provide an environment which will support and contain biological material as a substantially integral mass within said voidage, there being an extensive area of access from the outer surface of the or each said body to the voidage therein, means for causing the nutrient and any additional substances required for the process to contact and enter the support medium within the vessel, means for causing relative movement between the support medium and the walls of the vessel during the growth process, and means for restricting accumulation of biological material outwardly from the outer surface of the or each said body.

7. Apparatus according to Claim 6, wherein said vessel contains a multiplicity of said bodies each of which:-

(a) is of such shape as to enable the bodies to move relative to one another with a rubbing and/or knocking action without packing together as a solid unit; and

(b) has an outer surface of such character that the bodies do not interlock with one another during such relative movement; there being means for passing fluid containing the nutrient material and any additional substances required for the process, through the vessel under such conditions that there is some movement of the individual bodies relative to one another such that biological material which grows outwardly from the outer surfaces thereof is released through attrition.

8. Apparatus according to Claim 6, and for carrying out the method of Claim 3, wherein said vessel contains a multiplicity of said bodies each of which has an outer surface of such character that the bodies do not interlock with one another during relative movement, there being means for introducing said bodies free or substantially free of biological material to the vessel and means for removing bodies supporting and substantially filled with biological material from the vessel, the residence time of the bodies in the vessel being such that they are removed before growth of biological material outwardly from their outer surfaces occurs.

9. Apparatus according to Claim 8 wherein the bodies which are removed are freed from biological matter for recycling to the vessel.

10. Apparatus according to any one of Claims 6 to 9 inclusive wherein each said body is of toroidal shape and formed by rolling a length of tube knitted from a plastic monofilament into such shape.

11. Apparatus according to any one of Claims 6 to 9 inclusive wherein each said body is of generally spherical shape and is formed by crushing a length of tube knitted from a monofilament of stainless steel.

12. Apparatus according to any one of Claims 6 to 11 inclusive wherein each said body is of such size that the biological matter contained therein may be



source of nutrient. Thus the techniques may be applied to the production of pharmaceutical substances and single cell proteins such as yeast. It is envisaged, for example, that fermenters used in the brewing and related industries might usefully contain the necessary yeast within bodies of the general kind which we have described.

It will be understood that the bodies, even whilst empty, may serve to act as a filter in the apparatus described with reference to Figure 2 and in some applications such filtration effect might be advantageous.

CLAIMS

1. A process wherein a biological material is grown from a supply of suitable nutrient material, comprising the steps of providing a vessel in which is contained a biological material support medium in the form of at least one body defining within its internal structure a substantial voidage such as to provide an environment which will support and contain biological material as a substantially integral mass within said voidage, there being an extensive area of access from the outer surface of the or each said body to the voidage therein; causing the nutrient and any additional substances required for the process to contact and enter the support medium within the vessel there being relative movement between the support medium and the walls of the vessel during the growth process; and restricting accumulation of biological material outwardly from the outer surface of the or each said body.

2. A method according to Claim 1, wherein the restriction of accumulation of biological material outwardly from the outer surface of the or each said body is effected by continual or periodic removal of material growing outwardly from said outer surface.

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4. A method according to Claim 2, wherein said vessel contains a multiplicity of said bodies, and fluid containing the nutrient material is passed through the vessel under such conditions that there is movement of the individual bodies relative to one another such that biological material which grows outwardly from the outer surfaces thereof is released through attrition.

5. A method according to Claim 3, wherein said vessel contains a multiplicity of said bodies and fluid containing the nutrient material is passed through the vessel under such conditions that there is some movement of the individual bodies relative to one another, bodies being continually or periodically removed from the vessel when supporting and substantially filled with biological material, the residence time of the bodies in the vessel being such that they are removed before growth of biological material outwardly from their outer surfaces occurs, bodies which are free or substantially free of biological material being introduced into the vessel to replace those removed.

6. Apparatus for carrying out a process wherein a biological material is grown from a supply of suitable nutrient material, comprising a reaction vessel, a biological material support medium contained within the vessel, said support medium comprising at least one body defining within its internal structure a substantial voidage such as to provide an environment which will support and contain biological material as a substantially integral mass within said voidage, there being an extensive area of access from the outer surface of the or each said body to the voidage therein, means for causing the nutrient and any additional substances required for the process to contact and enter the support medium within the vessel, means for causing relative movement between the support medium and the walls of the vessel during the growth process, and means for restricting accumulation of biological material outwardly from the outer surface of the or each said body.

7. Apparatus according to Claim 6, wherein said vessel contains a multiplicity of said bodies each of which:-

(a) is of such shape as to enable the bodies to move relative to one another with a rubbing and/or knocking action without packing together as a solid unit; and

(b) has an outer surface of such character that the bodies do not interlock with one another during such relative movement; there being means for passing fluid containing the nutrient material and any additional substances required for the process, through the vessel under such conditions that there is some movement of the individual bodies relative to one another such that biological material which grows outwardly from the outer surfaces thereof is released through attrition.

8. Apparatus according to Claim 6, and for carrying out the method of Claim 3, wherein said vessel contains a multiplicity of said bodies each of which has an outer surface of such character that the bodies do not interlock with one another during relative movement, there being means for introducing said bodies free or substantially free of biological material to the vessel and means for removing bodies supporting and substantially filled with biological material from the vessel, the residence time of the bodies in the vessel being such that they are removed before growth of biological material outwardly from their outer surfaces occurs.

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11. Apparatus according to any one of Claims 6 to 9 inclusive wherein each said body is of generally spherical shape and is formed by crushing a length of tube knitted from a monofilament of stainless steel.

12. Apparatus according to any one of Claims 6 to 11 inclusive wherein each said body is of such size that the biological matter contained therein may be



sufficiently large in volume whereby both aerobic processes and anaerobic processes will take place therein when the body is in an oxygen containing environment.

5 13. Apparatus according to any one of Claims 6 to 12 inclusive where the necessary nutrients are carried by a fluid medium for flow over the body or bodies.

14. Apparatus according to Claim 13 wherein
10 said fluid medium comprises a liquid.

15. Apparatus according to Claim 14 wherein a gaseous medium is additionally caused to flow over the body or bodies.

16. Apparatus according to any one of Claims 6
15 to 15 inclusive used for the treatment of industrial or sewage effluent which constitutes the source of nutrient, oxygen being provided to the interior of the vessel to meet the biological oxygen demand.

17. A process wherein a biological material is
20 grown from a supply of suitable nutrient material, substantially as described herein with reference to and as illustrated by the several figures of the accompanying drawings.

18. Apparatus for carrying out a process wherein
25 a biological material is grown from a supply of suitable nutrient material, substantially as described herein with reference to and as illustrated by Figures 1, 3 and 4 or Figures 2, 3 and 4 of the accompanying drawings.

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