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[54] Title: METHOD AND APPARATUS FOR MEASURING THE TURBIDITY

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[56] Reference (s) Cited and/or Considered:

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[57] (see abstract next page)

26848

METHOD AND APPARATUS FOR MEASURING THE TURBIDITY OF A LIQUID

ABSTRACT

The present invention relates to a method of measuring the turbidity of a liquid comprising placing a measuring cell in the liquid to be analyzed in such a way that a sensor may have a light receiving surface looking upward, supplying air intermittently to clean said light receiving surface, allowing bubbles to float to remove them from said cell, radiating light to said liquid and detecting scattering light through said sensor.

DETAILED DESCRIPTION OF THE INVENTION

Field of the Invention:

This invention relates to a method of, and an apparatus for, measuring the turbidity of a liquid. More particularly, it relates to a turbidimetric method and apparatus which are suitable for determining the concentration of a suspended substance in activated sludge or pulp waste, or the concentration of microorganisms in a fermented solution or waste of fermentation.

Prior Art:

Methods for measuring the turbidity (concentration) of a liquid are classified into ultrasonic methods, radioactive methods and methods relying on light. The methods relying on light are classified into a method using transmitted light and a method using scattering light. In either case, the presence of bubbles in a liquid disables accurate measurement. Especially, no method has been established as yet for the on-line determination of the concentration of microorganisms in a fermentation process.

A variety of methods have been proposed for removing bubbles, as follows:

1) Adding a antifoaming agent to the liquid to be analyzed;

2) Applying pressure to the liquid in a sampler;

3) Using a net for removing bubbles;

4) Using a sampler having an inner tube and an outer tube and causing a liquid to flow up the inner tube and down the outer tube so that bubbles rising in the outer tube may be separated from the liquid; or

5) Drawing a liquid into a sampler by a piston and leaving it at rest so that bubbles rising in the sampler may be discharged through its liquid inlet.

Problems to be Solved by the Invention:

The conventional methods as hereinabove described have, however, presented the following problems:

(a) All of the methods are prevented by bubbles from making accurate measurement;

(b) The optical system is easily contaminated, resulting in the failure to make accurate measurement; and

(c) The turbidimeter is complicated in construction and easily stained, forming a cause for contamination by various germs especially in fermentation and cultivation.

This invention has been made to solve those problems. It is an object of this invention to provide a method of, and an apparatus for, measuring the turbidity of a liquid which are efficient, quick in response and accurate, by employing an improved measuring cell of simplified construction which facilitates the removal of bubbles and the cleaning of a light receiving surface, and combining it with an optical fiber system for detecting scattering light.

Means for Solving the Problems:

This object is attained by a method comprising placing a measuring cell in the liquid to be analyzed in such a way that a sensor may have a light receiving surface looking upward, supplying air intermittently to clean the light receiving surface, allowing bubbles to float to remove them from the cell, radiating light to the liquid and detecting scattering light through the sensor, and an apparatus

comprising a sensor containing optical fiber in a cylindrical body having one end setting a light receiving surface, a measuring cell for holding the liquid to be analyzed, the cell having one end joined to the one end of the sensor body and another end that is open, the cell having a cylindrical wall formed at the one end of the cell with an air nozzle substantially facing the light receiving surface, and means for supplying air under pressure to the nozzle intermittently.

The invention will now be described more specifically with reference to the drawings.

FIGURE 1 shows a measuring system forming the principle of this invention. Light d is radiated from a light source c to a fluid b flowing about optical fiber a, and scattered by a suspended substance in the fluid b. The backwardly scattered light e passes through the optical fiber and is filtered by an interference filter f (e.g. 560 nm). It is converted by a photodiode g to an output voltage. The output voltage is transmitted through an amplifier h and a filter i and recorded on a recorder j. The voltage is read from the recorder and used for calculating the turbidity of the liquid.

FIGURE 2 shows a turbidity measuring apparatus (turbidimeter) embodying this invention. The turbidimeter A comprises optical fiber 3, a protective cover 1 for the optical fiber and a measuring cell 2 for holding the liquid to be analyzed. The cover 1 comprises a cylindrical body 4 for protecting the optical fiber 3 and a transparent glass light receiving surface 5 or light-transmitting plastic light receiving surface 5 (serving also as a light projecting surface) provided at one end of the body 4. The measuring cell 2 comprises a cylindrical body 4' extending from the light

receiving surface 5 and terminating in an open end 6. The body 4' is formed at one end with an air nozzle 7 substantially facing the light receiving surface 5. The nozzle 7 is provided with an electromagnetic valve 8 which is alternately turned on and off at regular intervals for supplying air under pressure to the light receiving surface 5 intermittently. A timer 9 is provided for the valve 8.

Operation:

Description will now be made of a method for the on-line measurement of the turbidity of a liquid.

The apparatus of this invention is immersed in the liquid to be analyzed on line, and so positioned that the light receiving surface 5 may look upward. If the liquid to be analyzed flows through a pipe, the cell 2 is so positioned that its open end 6 may look upward.

The electromagnetic valve 8 is alternately turned on and off at regular intervals to blow air against the light receiving surface 5 intermittently through the nozzle 7. This air removes all staining matter from the light receiving surface 5 and keeps it clean. The air also serves to prevent any old liquid from remaining in the cell 2 and enable a fresh liquid to fill the cell 2. If the supply of air is discontinued, bubbles rise along the cell 2 and are separated from the liquid. When all bubbles have been separated from the liquid, it is possible to measure its turbidity.

The measuring system (FIGURE 1) is connected to the optical fiber 3 by inserting top of a in Figure 1 into 4 of Figure 2. The part of 3 in Figure 2 is the same as the part of a (optical fiber) in Figure 1.

The light scattered by the liquid is converted to an electric current by the photodiode g. Its output voltage is read and compared with a working curve, which has to be prepared beforehand, whereby it is possible to determine the turbidity or concentration of the liquid. Upon completion of the measurement, the electromagnetic valve 8 is turned on and off to blow air into the cell 2 to clean the light receiving surface 5 and purge the cell 2 so that the apparatus may be ready for another cycle of measurement.

Although the duration of air supply through the nozzle 7 depends on the nature of the liquid to be analyzed, a period of two to 10 seconds is usually sufficient for satisfactory cleaning and purging purposes. While the time required for the removal of bubbles also depends on the nature of the liquid, it has been found that a period of several tens of seconds is sufficient for the complete defoaming of activated sludge, and a period of one to two minutes for a fermented amino acid solution.

The invention will now be described more specifically with reference to several examples thereof.

EXAMPLE 1:

A small fermentation vessel having a capacity of one liter was charged with 600 ml of cane molassess and a turbidimeter according to this invention was inserted therein so that it might look upward at an angle of 20° to the horizontal. Brevibacterium lactofermentum (ATCC13869) was cultured in the vessel at an aeration rate of 600 ml/min. and an agitating speed of 1000 rpm. Examination was made as to whether the turbidimeter worked for complete defoaming. Air was supplied through the nozzle at a rate of 600 ml/min.

intermittently for a period of 30 seconds followed by an interruption of 2.5 minutes. The intermittent supply of air was continued throughout the period of the culture. When the supply of air was interrupted, bubbles were separated from the liquid and the output voltage of the system dropped to a substantially constant level, as shown in FIGURE 3. As the culture proceeded, the value of the said constant level output voltage showed an increase indicating the growth of microorganisms.

EXAMPLE 2:

The test of EXAMPLE 1 was continued until after cane molassess had been consumed by microorganisms resulting in the termination of their growth. When 36 hours had passed after the beginning of the culture, the light receiving surface (protective glass) of the turbidimeter was wiped carefully by hand. Comparison was made between the output voltages in an area marked b in FIGURE 4 before and after the wiping. No difference deviating from a tolerable range was found, as is obvious from FIGURE 4.

EXAMPLE 3:

A vessel having a capacity of one liter was charged with 600 ml of water and 2.2 g per liter of activated sludge which had been collected from the processed sewage of our company. A turbidimeter according to this invention was inserted therein so that it might look upward at an angle of 20° to the horizontal. The contents of the vessel were aerated at a rate of 600 ml/min. and agitated at a speed of 1100 rpm. The procedure of EXAMPLE 1 was repeated for the intermittent supply of air through the nozzle. When the supply of air was interrupted, bubbles were separated from the liquid and the

output voltage dropped to a substantially constant level, as shown in FIGURE 5.

EXAMPLE 4:

The test of EXAMPLE 3 was continued for 100 hours and the light receiving surface was examined as to whether it had been contaminated. When the 100 hours had passed, the light receiving surface was wiped carefully by hand, and comparison was made between the output voltages in the area marked b in FIGURE 6 before and after the wiping. No difference deviating from a tolerable range was found, as is obvious from FIGURE 6.

Advantages of the Invention:

The invention as hereinabove described has the following advantages:

(1) The apparatus is so simple in construction that it is easy to manufacture, operate and inspect;

(2) Bubbles are easy to remove and do not have any adverse effect on measurement;

(3) The supply of air through the nozzle protects the optical system (light receiving surface) against contamination;

(4) It is sufficient to immerse the apparatus in the liquid to be analyzed in order to achieve the on-line measurement of its turbidity easily; and

(5) Good efficiency and reproducibility, and accurate measurement.

WHAT IS CLAIMED IS:

1) A method of measuring the turbidity of a liquid comprising placing a measuring cell in the liquid to be analyzed in such a way that a sensor may have a light receiving surface looking upward, supplying air intermittently to clean said light receiving surface, allowing bubbles to float to remove them from said cell, radiating light to said liquid and detecting scattering light through said sensor.

2) An apparatus for measuring the turbidity of a liquid comprising a sensor containing optical fiber in a cylindrical body having one end setting a light receiving surface, a measuring cell for holding the liquid to be analyzed, said cell having one end joined to said one end of said sensor body and another end that is open, said cell having a cylindrical wall formed at said one end of said cell with an air nozzle substantially facing said light receiving surface, and means for supplying air under pressure to said nozzle intermittently.

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Figure 1

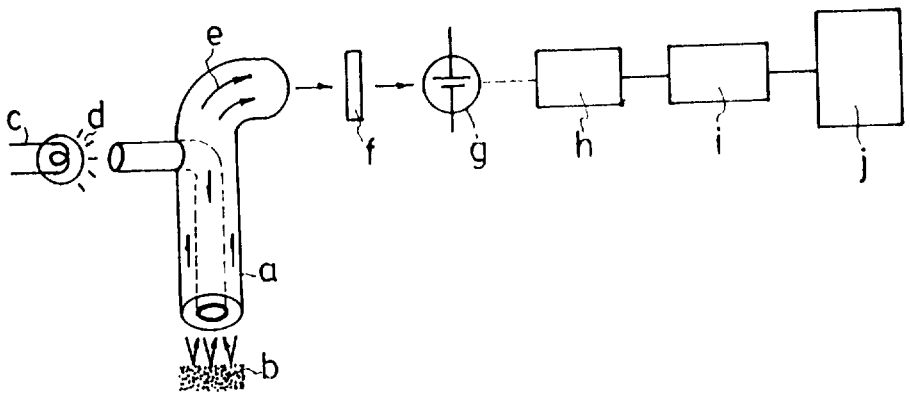

FIGURE 2

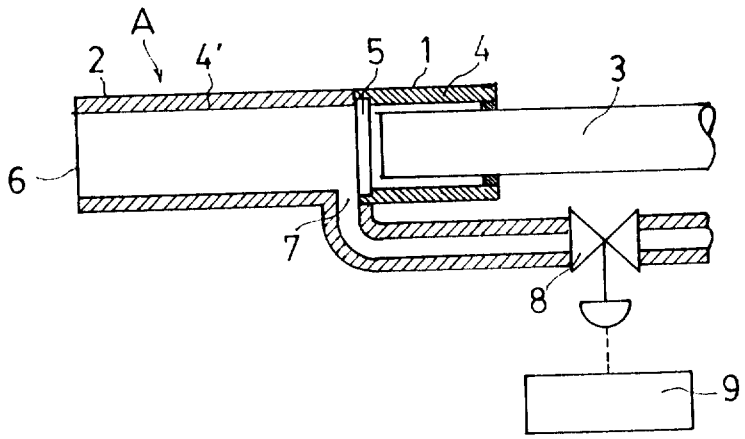

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Figure 3

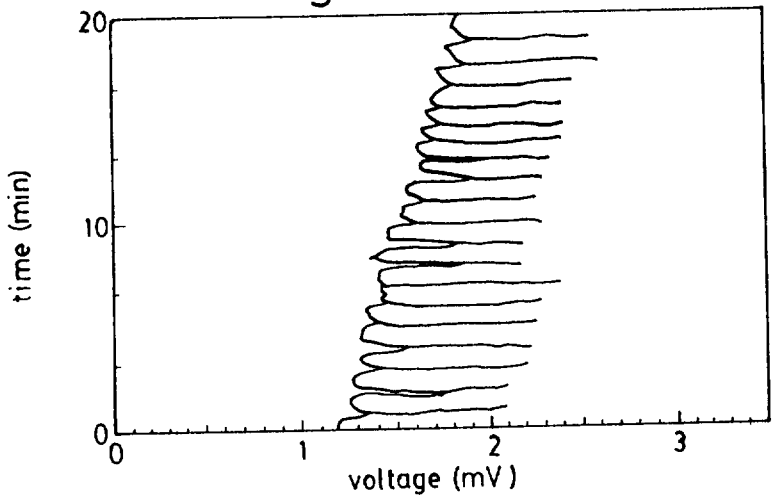

Figure 4

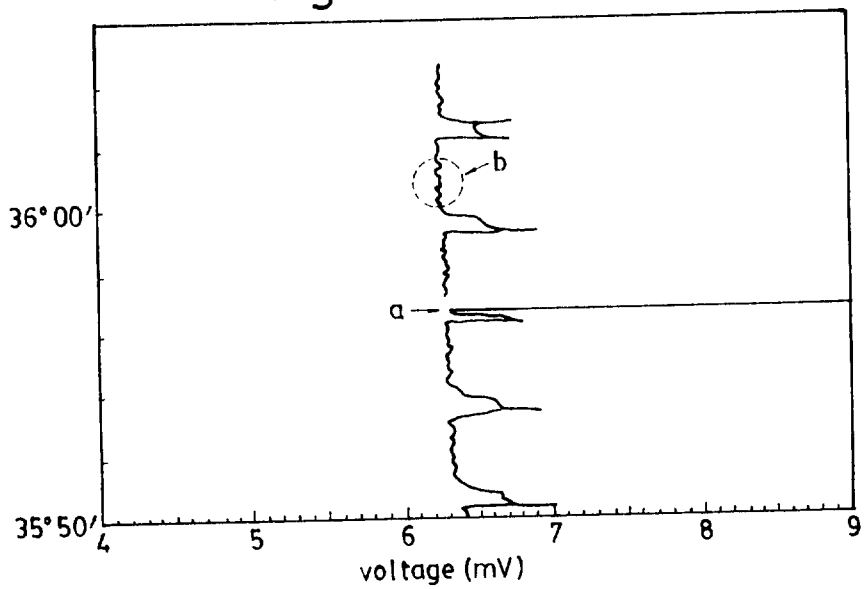

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Figure 5

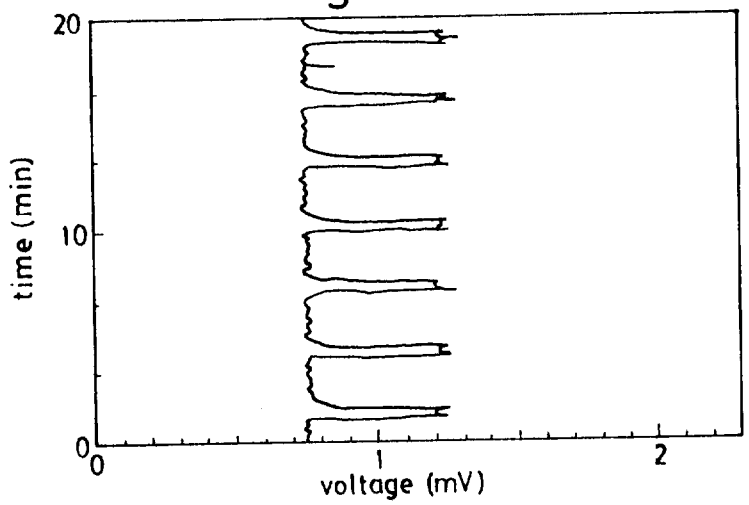
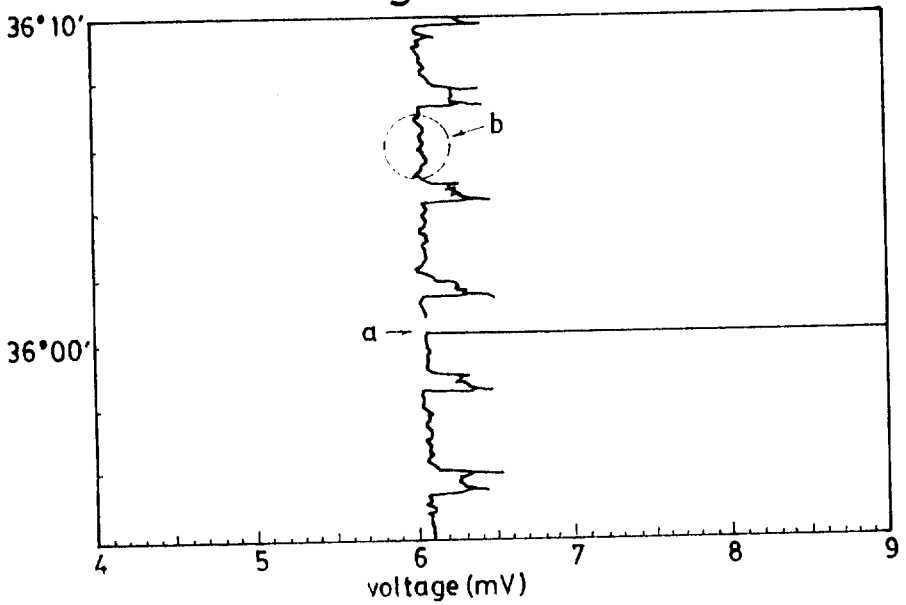


Figure 6



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