UDC 628.315:628.353:579.6

FIXED-FILM ANAEROBIC-AEROBIC BIOREACTOR SYSTEM FOR SEWAGE TREATMENT

Kousei Sasaki
Shigeru Hatsumata
Katsuo Iha

1. FOREWORD

Recently, the development of biotechnology has been amazing and good results have been obtained in many fields.

Because biological treatment has been the mainstream of sewage treatment from times past, it is no exaggeration that the possibilities which can use this advanced technology are extremely large.

Since 1985, the Ministry of Construction has been proceeding with a five year plan for developing new waste water treatment systems (bio-focus W.T.) using biotechnology. This project is attempting to develop revolutional sewage treatment technology.

Fuji Electric, in cooperation with the Public Works Research Institute of the Ministry of Construction, was in charge of development of a fixed-film anaerobic-bioreactor in this bio-focus W.T. For this research, Fuji Electric applied microorganism immobilization technology, a key element of the biotechnology, to methane fermentation technology nurtured over may years and configured a waste water treatment plant as an anerobic bioreactor. Because treatment with the previously mentioned bioreactor only is inadequate, we also developed independently an aerobic bioreactor and an anaerobic bioreactor for sludge treatment for post-treatment use.

At Fuji Electric, a system incorporating the previously mentioned bioreactors is named the Fuji Anaerobic Bioreactor System (FABS) and a pilot plant is now being demonstrated.

An outline of the FABS, centered about the result of the pilot plant demonstration, is introduced here.

2. PRINCIPLE AND FEATURES

2.1 Principle of bioreactor

The fixed-film bioreactor developed by Fuji Electric purifies sewage by means of the microorganisms attached to the media immersed in a tank.

An anaerobic-bioreactor is a tank whose interior is maintained anaerobic (oxygen-free state) and the anaerobic-microorganisms are immobilized to the media. On the other hand, an aerobic reactor is fed with air (oxygen) and aerobic-microorganisms are immobilized. The biggest feature of the FABS is the methane fermentation of sewage by large amount of anaerobic microorganisms immobilized in a tank. The principle of methane fermentation in the reactor is shown in *Fig. 1*. The organic substances in the sewage are decomposed into carbon dioxide gas and methane gas by anaerobic microorganisms. *Fig. 2* is a microscope photograph of the immobilized anaerobic microorganisms.

The FABS treatment flow is in anaerobic bioreactor and aerobic bioreactor order. The treatment mechanism as a system is outlined in *Fig. 3*. In the anaerobic bioreactor, 20% to 40% of the organic substances in the raw sewage are decomposed to carbon dioxide gas and methane gas and removed. When the part removed as sludge is added to this, 50% to 70% of the organic substances in the raw sewage is removed at the anaerobic reactor. Most of the remaining organic substances is removed by the following aerobic reactor. The water discharged from this reactor is effluent with few organic substances.

Fig. 1 Removal of organic substances in an anaerobic bioreactor (methane fermentation)

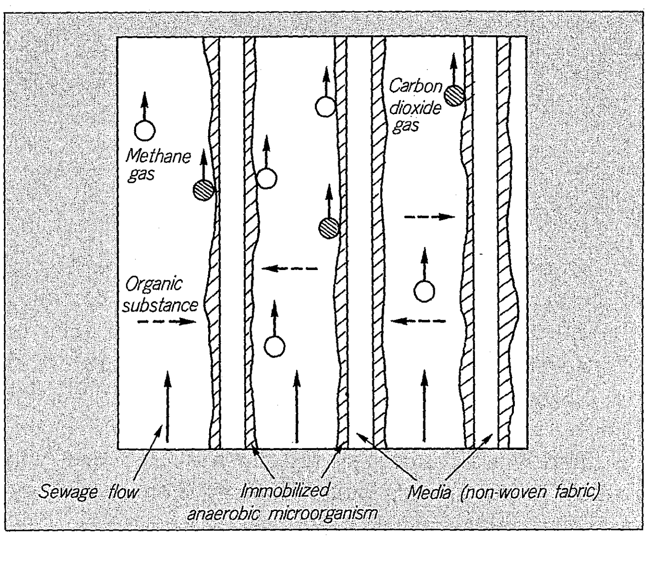


Fig. 2 Microscope photograph of immobilized anaerobic microorganisms

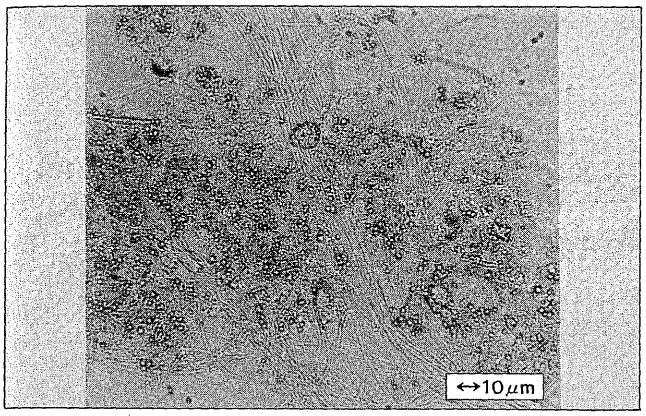
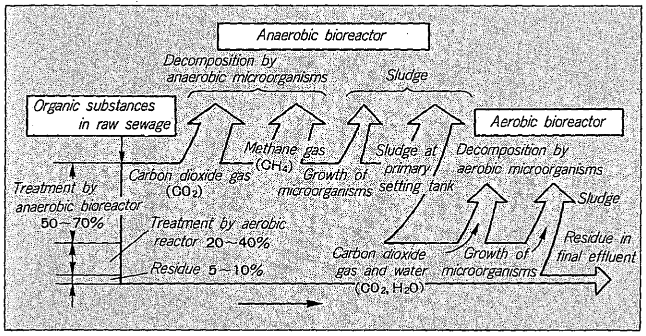


Fig. 3 Mechanism of sewage treatment by bioreactor



2.2 Features of FABS

(1) Energy-saving, low cost.

Since sewage is mainly anaerobicaly treatmented, the energy required for aeration can be cut down.

(2) Low sludge production

Because organic substances are gasified as a result of anaerobic treatment, the amount of sludge produced in a system becomes small.

(3) Good water quality

Since finishing treatment is performed by an aerobic reactor, good water quality is obtained.

(4) Simple maintenance and management

Since the media is fixed and sludge is discharged automatically, operating factors are small and maintenance is easy.

From the features above, this system is suitable for small-sized sewage treatment systems, the need for which is expected to rise in the future.

3. PILOT PLANT DEMONSTRATION

3.1 Plant

An exterior view of the pilot plant and a flow sheet are shown in *Fig. 4*, *Fig. 5*. Its main specifications are shown in *Table 1*. The plant is installed at a bio-focus yard (Tsuchiura City, Ibaragi Prefecture). The treatment capacity is 20 to $30m^3$/day and the retention time is 16 to 24 hours.

Fig. 4 FABS pilot plant

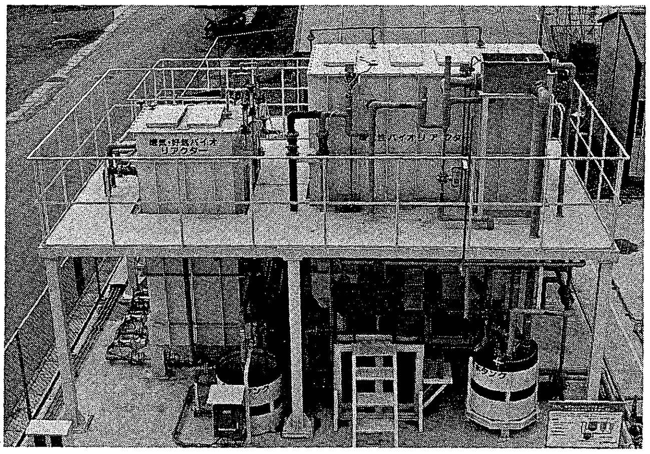


Table 1 Main specifications of FABS pilot plant

Feed	Raw sewage
Treatment capacity	$20\sim30^3$/d
Retention time	16~24 hrs
Media	Non-woven fabric

The demonstration period is scheduled to be from June 1988 to March 1990. The plant is currently being demonstrated from various angles.

This plant consists of a sewage treatment process and a sludge treatment process.

The anaerobic reactors are operated in an upflow mode, and their bottoms serve as settling tanks. The raw sewage flows in directly to the anaerobic reactor. The modular media made of non-woven fabric shown in *Fig. 6* was used to immobilize anaerobic microorganisms. Non-woven fabric is a material in a vertical mesh. A mesh roughness of 100 to 500 μm is used here.

The aerobic bioreactor is for finish treatment. It is packed with the same modular media made of non-woven fabic. The operating mode of the intermediate anaerobic/aerobic reactor can be switched. In the winter, it is operated in the aerobic mode. The upper section of the anaerobic bioreactor for sludge treatment is packed with media and the bottom is a sludge digester with no stirrer or heater (methane fermentation tank), which also serves as a sludge storage tank. The sludge discharged automatically from the sewage treatment process is anaerobically digested in the storage tank and sludge-volume is reduced here. The media used here is a short plastic pipe covered with non-woven fabric (raschig ring with non-woven fabric) and is packed at random.

This pilot plan is configured as a total system made up of a sewage treatment process and a sludge treatment process, and can be considered to be the small-sized system of the actual plant.

Fig. 5 FABS pilot plant flow sheet

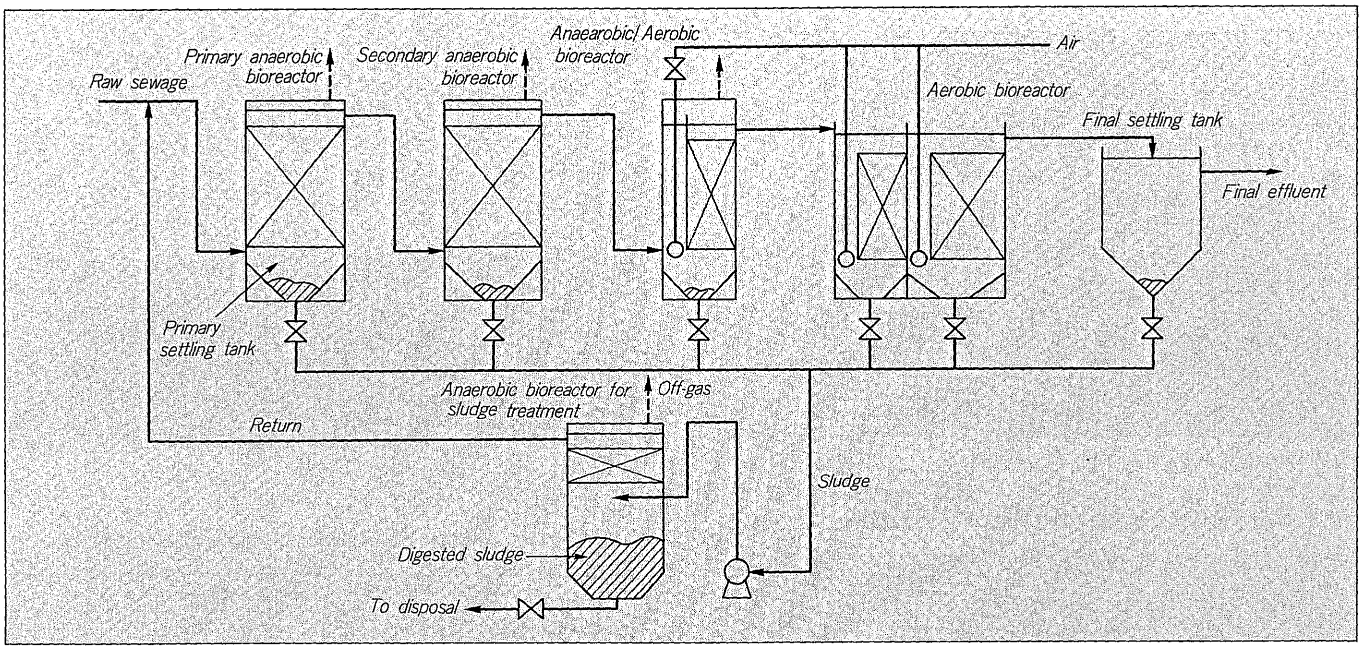
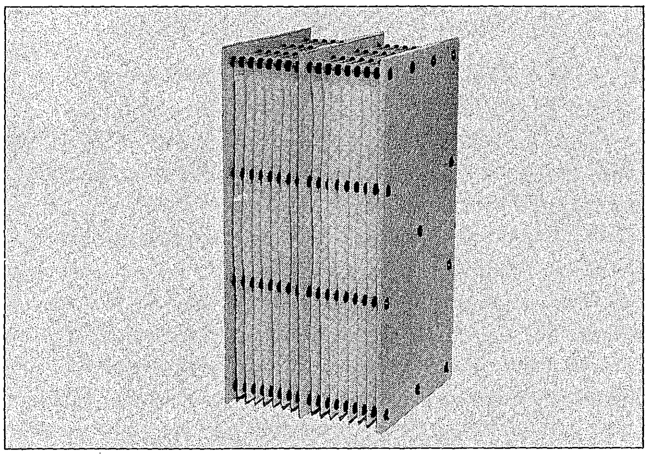


Fig. 6 Modular media made of non-woven fabric



3.2 Results and discussion

Since this plant is still in operation, the initial operation results are reported here.

(1) Reactor start-up period

Since the growth rate of anaerobic microorganisms is slow, six months were usually needed until sufficient microorganisms became attached to the media and the expected performance of the anaerobic bioreactor was obtained. To shorten this long start-up period, Fuji Electric hase developed a new method of the start-up by placing media modules dipped in digested sludge containing a large amount of anaerobic microorganisms in advance. This method also used with this plant. Referring to *Fig. 7*, after 50 days, the effluent BOD of the anaerobic reactor stabilized at 30 to 35mg/*l*. The quality of the final effluent also became approximately 10mg/*l* simultaneously. The methane gas generation was confirmed from the 20th day and stabilized at 10 to 15*l*/d from the 50th day. The average temperature during this period was 21°C.

From the results above, it was confirmed that when the water temperature is about 20°C, the anaerobic reactor and the treatment system can be started in approximately two months.

(2) Retention time and water quality

The relationship between retention time and water quality is shown in *Fig. 7*. The reactor was started under 24 hours retention time and good water quality was obtained, as previously mentioned.

The retention time was then shortened to 16 hours, but the water quality was similarly good. However, when the retention time was shortened to 13.4 hours (anaerobic 10.5, aerobic 2.9), the water quality tended to become worse and it was observed that overloading occured under this condition. Referring to *Fig. 7*, when the BOD and SS removal conditions were studied, most of the organic substances were removed by the anaerobic reactor. This reduces loading to the aerobic reactor and is related to energy-saving of the entire system.

Currently, the treatment efficiency over the 16 to 24 hours retention time range is being evaluated.

(3) Sludge production

At this plant, the sludge which is to be discharged from the plant is exhaustively reduced in volume through anaerobic digestion of the sludge produced in reactors. The volume of methane gas generated by the anaerobic reactor for sludge treatment is shown at the top of *Fig. 7* and the proportion of digested sludge volume accumulated in the reactor to the volume of accumulated effluent is shown in *Fig. 8*. The volume of methane gas stabilized at 60 to 90 *l*/d after the 80th day, but dropped slightly by lowering of the temperature from the 150th day. On the other hand,

Fig. 7 Pilot plant water quality and methane gas generation

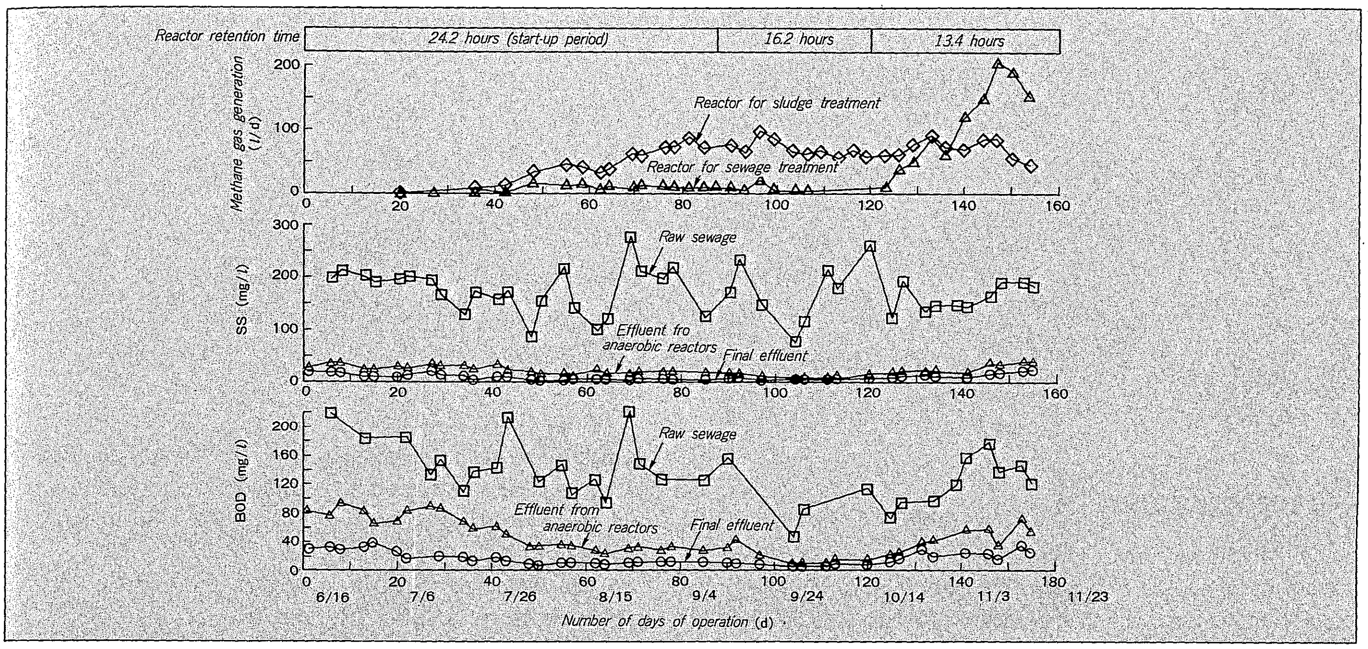
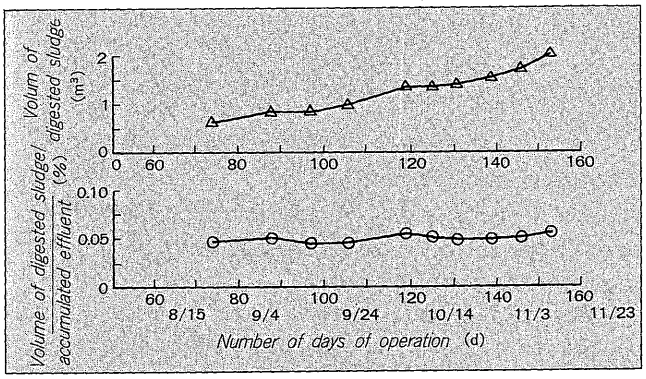


Fig. 8 Proportion of volume of digested sludge to volume of effluent



the volume of digested sludge increased with the number of days, but the proportion relative to the accumulated effluent volume became a very low 0.05%. For a small scale treatment plant, since the sludge production is generally reported to be about 0.5 to 1%, the sludge production described above is rather small. The demonstration result of *Fig. 8* proves the features of this system.

4. CONCLUSION

As described above, the sewage treatment system using the anaerobic and aerobic bioreactors is a biotechnology-applied system. Its biggest feature is methane fermentation of sewage. Therefore, this system can save energy and reduce sludge production. These advantages are being proved by the pilot plant.

In the future, we plan to accumulate technology and establish basic design through demonstration experiment and want to offer it as the small scale sewage treatment system for which a need is increasing already.